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SEWER AND WATERMAIN CONSTRUCTION INSPECTORS' COURSE No.1

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Ministry of the Environment

municipal engineers association
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SEWER AND WATERMAIN

CONSTRUCTION INSPECTORS

COURSE NO. 1

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PREFACE

The topic content of this Manual has been prepared to assist inspectors concerned with the construction of linear type services. It is not presented in the form or detail of a textbook, but rather is a compilation of practical information with which the inspector on sewer and watermain construction projects should be familiar. The topic material was prepared principally by members of the MEA-MOE Inspectors' Course Development Group, on which there is representation by municipalities, consulting engineers, and the Ministry of the Environment. Some material also was contributed by specialists from industry. It is anticipated that the Manual will be reviewed and up-dated when necessary. In that respect, comments and constructive criticism are invited.

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SUBJECT:

CONSTRUCTION OF SEWERS
WATERMAINS AND
ASSOCIATED FACILITIES

TOPIC: I

ROLE OF THE INSPECTOR

OBJECTIVES:

The trainee will be able to:

1. Understand the role of the inspector concerning:

   a) duties to the owner and contractor;

   b) maintenance of public relations in the Municipality.

ROLE OF THE INSPECTOR

The importance of the inspector on a construction project cannot be over-emphasized. He is the day to day link between the owner and the consulting engineer on the one hand and the contractor on the other hand. Although the main duty of the inspector is to protect the interests of the owner, in carrying out that duty he must be fair to the contractor. The inspector should be polite in his dealings with others but firm in his insistence that the contractor construct the works properly and in accordance with the contract.

Most contracts make the contractor responsible for complying with all applicable by-laws and safety regulations and for carrying out the works in such a manner as will not cause unreasonable or unnecessary inconvenience to the public. It is one of the duties of an inspector to check that the contractor complies with these requirements and when necessary to remind him and even order him to comply.

The inspector is often the last man who has the opportunity to spot mistakes such as dimensional discrepancies or deterioration of soil conditions before the affected part of the works has been constructed and any necessary corrections have become an expensive item. The inspector should be wary about making corrections or modifications himself but should in general refer such matters to his head office and obtain directions from those responsible for the design of the works.

The method of construction and the construction plant to be used are generally the contractor's choice and responsibility (except when, because of a special

design or particular soil conditions, the contract specifies the method or plant to be used). There will be times, however, when it becomes apparent to the inspector that the method or plant being used by the contractor is unsuitable for the job in hand. The inspector should then point out to the contractor the unsuitability of the method or plant and may, if he is sufficiently experienced and confident, and if requested by the contractor suggest a better way. The inspector must, however, avoid running the contractor's job for him. In extreme cases, if the method or plant being used is likely to be a danger to people, property or the works, the inspector may have to order the contractor to stop work or change his method but such action should preferably only be taken after consultation by the inspector with his head office.

The inspector should try to spot sub-standard materials and workmanship as early as possible and point them out to the contractor immediately so that the amount of unsatisfactory work requiring taking out and re-doing is kept to a minimum.

An important aspect of an inspector's job is the maintenance of good public relations in the municipality. If the inspector takes the trouble to give the local authorities, property owners and tenants notice of proposed interruption of existing services, temporary blocking of streets, blasting operations, etc., he will find that people are generally more co-operative and more willing to put up with such inconveniences. The period of inconvenience will be shortened and hence public relations improved if clean-up follows closely behind construction on streets and easements. Few contractors will carry out restoration and clean-up promptly of their own accord as they tend to look upon such work as a non-paying item. The public, on the other hand, tends to judge a sewer or watermain job by what is visible above ground and usually, after backfilling has been completed,

all that is visible is restoration and clean-up. The inspector must, therefore, keep close watch on such work and insist that the contractor carries it out promptly.

In dealing with the public, the inspector must be careful not to make rash promises. He cannot commit the contractor to work which is not required by the contract and he must not commit the owner to additional work without first having the matter approved by the owner through the inspector's head office.

The responsibility and authority of an inspector is normally set out in the General Conditions of Contract. In the General Conditions, the object is to set forth both the general duties, authority, responsibility and relationships of the contracting parties and their representatives in the actual conduct of the work, whether in the office or in the field. General Conditions may and frequently do vary from owner to owner.

Therefore the Inspector should familiarize himself with the General Conditions of any contract for which he is required to perform inspection duties.

SUBJECT:

CONSTRUCTION OF SEWERS
WATERMAINS AND
ASSOCIATED FACILITIES

TOPIC: 2

RECORDS

OBJECTIVES:

Trainee will be able to:

1. Understand the importance of accurate and detailed records.

2. Organize records of work progress.

RECORDS

GENERAL

One very important function of the inspector is to keep records as the job progresses. It is essential to record work progress, daily events, weather and soil conditions, location of rock, uncharted underground obstructions or services, failures of the contractor as well as any remedial action taken.

Records should be comprehensive and accurate so that they will stand up before any court of law. The inspector should always assume that his firm or municipality may be required to substantiate its action in court and keep his records accordingly. When litigation does take place a court will put greater reliance on reports, properly prepared at the time, dated and signed, rather than on a person's memory of events which took place many months or years before.

OVERALL RECORDS

Whereas record keeping practices vary from municipality to municipality or from employer to employer, the basic ideas presented below do not vary.

It is the inspector's duty to be able to locate any installation done under his supervision at any time. He must also be able to compute and substantiate the quantities comprising the contract. To be able to do so, he must keep a fairly comprehensive set of records.

The following sections will outline some of the most common and basic records that should be kept.

Preconstruction Records

Preconstruction records are required to outline the existing condition of pavement and ground surfaces, structures, streets, and shrubs along the routes the works will take. As is outlined in the topic "Restoration" this written and/or photographic record is vital to ensuring that proper restoration takes place. The record should be made prior to the start of construction and should outline any areas of possible contention in the future. Any photographs taken should be labelled with date, location (by chainage number), project name and contract number.

Works Diary

The work diary should consist of a book with a hard cover and be kept up-to-date at all times. It should never be a loose leaf book since pages can be added or removed at a later date. Every daily page must be signed by the person making the entry and these daily entries generally should consist of:

1. date
2. weather conditions, high and low temperatures
3. size of work force
4. equipment on site
5. location where contractor worked
6. progress of works
7. special events, accidents, etc.
8. orders given to the contractor
9. site meetings
10. visitors to the site
11. instructions received from superiors
12. description of soil conditions encountered
13. any equipment or materials delivered to the works for incorporation in the works
14. comments entered by the contractor
15. any other relevant information or comments

Daily or Weekly Reports

The daily or weekly reports should be prepared in triplicate as required. One copy should be kept by the inspector for his personal records.

The contents of the daily report should be the source for the daily entries in the diary.

The advantage of the daily or weekly report is that the inspector's superiors and the owner are kept informed of the progress of the work as well as of special events and difficulties encountered on the site. Thus they are able to take action when required without undue delay.

Daily reports should include the following:

1. Project name, contractor's name, owner's name, project number, contract number.

2. Date, weather, temperature.

3. Day's progress (by chainages and lengths).

   - trenching completed
   - pipe installed (describe any "specials" installed)
   - bedding completed
   - backfilling completed
   - surface restoration completed
   - rock excavation.

4. Appurtenances constructed

   - manholes (chainage and depth)
   - catch basins (chainage)
   - laterals (chainage and depth, size and length)
   - chambers (chainage)
   - valves (chainage)
   - crosses and tees (chainage)

5. Size, depth and chainage location of structures encountered:

   - centre line of roads crossed
   - utilities and service connections
   - underground chambers and structures.

6. Record:
   - type of soil encountered
   - extent of shoring used
   - ground water conditions
   - dewatering methods.

7. List major items of equipment and number of men on job for the general contractor and sub-contractors separately.

   - list materials delivered to job and condition.

8. Hours worked.

9. General comments:

   a) report any unusual happenings or incidents such as accidents as well as visitors to the site;
   b) record the results of any tests performed.

10. Signature of inspector:

    - the inspector should sign each day's report.

The daily report should be summarized weekly to form the basis of a weekly report which would be sent to the head office.

Record of Quantities

This record should be kept in accordance with the Schedule of Items and Prices of the contract documents.

The inspector should use a field book for keeping a record of the exact measurement of contract items up-to-date as the work progresses. Items difficult to prove later such as fill concrete, etc. should be recorded with sketches showing where the measurement has been taken. It is advisable to have such sketches initialled by the contractor or his foreman to avoid arguments later. This is especially important when dealing with force account items.

Rock excavated should be shown on the profiles of the construction drawings to allow proper calculation of the actual quantities. Rock elevations should be recorded in the inspector's field notes as well as on the drawings. The owner's representative should be able to obtain the quantity of work completed to date from this record at any time.

As-Built Records

The importance of as-built records cannot be overly emphasized. The following items should be recorded on the as-built records:

- existing ground (if different than on the drawings)
- structure and utilities encountered
- location, elevation, grade and sizes of installed pipe and appurtenances
- locations, length, sizes and surface ties for laterals, tees, bends and stubs (surface ties to be referenced to permanent structures)
- elevation of rock surfaces encountered
- unusual ground conditions
- support and sheeting left in place, anchor blocks, etc.

All the above measurements should be made at the actual time of construction particularly if the item is to be buried.

Photographic Records

The inspector should have a camera on the site. A polaroid camera would be most desirable because the picture can be marked and identified shortly after it is taken.

The photographic record if properly done can avoid many arguments later and also support the inspector's position in court if necessary.

A photo showing the conditions of a street or property before construction gives proof that the contractor did or did not reinstate the road to its original condition.

A picture taken of the excavated trench shows proof of underground conditions, of the contractor's safety practices, etc.

Any unexpected condition or faulty workmanship should be recorded by taking a photograph. The price of the film in comparison to the project cost is very little and should not be a reason for taking an insufficient number of pictures.

Every picture should be identified on the back with the following information:

1. Project and contract number.

2. Municipality

3. Location (station and view).

4. Date

5. Description

6. Photo taken by.

7. Witnessed by (if possible).

SUMMARY

Records comprise a large part of an inspector's job. If this portion is not done correctly he can cost the owner he is representing many dollars by not adequately documenting items of contention as well as materials used.

SUBJECT:

CONSTRUCTION OF SEWERS WATERMAINS AND ASSOCIATED FACILITIES

TOPIC: 3

BASIC SOILS

OBJECTIVES:

The trainee will be able to:

1. Understand Glaciation.
2. Understand classification of soils.
3. Be aware of some of the properties of different soil types.

BASIC SOILS

GENERAL

In order to have an understanding of soils and their characteristics it is essential to know how that soil was created and deposited in place.

In Ontario all soils have undergone the effects of glaciers. An understanding of glaciers is a key to understanding the land that was created.

GLACIERS

Glaciation History

A known minimum of four advances and retreats of glaciers occurred in Ontario. The most recent ice age is believed to have ended about 20,000 years ago. This most recent ice blanket reached to the south of Lakes Ontario and Erie. Previous ice blankets extended into Wisconsin.

Ice Movement

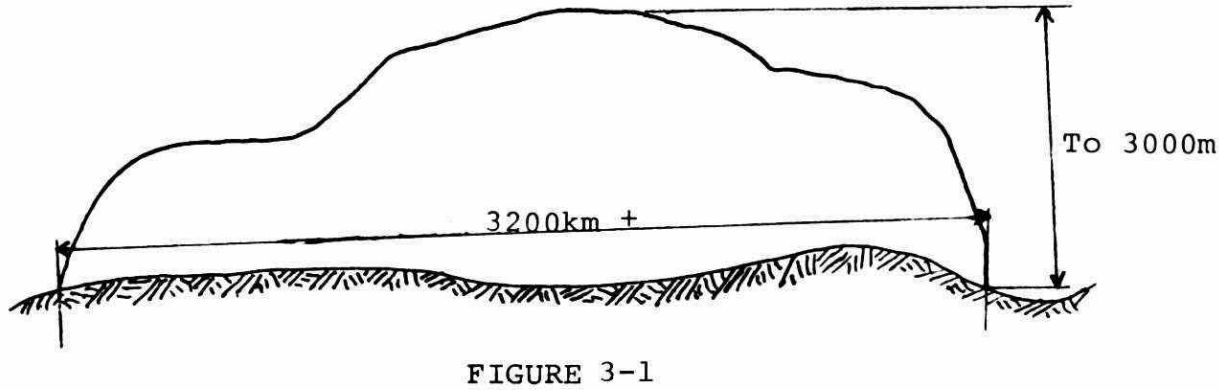


FIGURE 3-1

The immense weight of ice (e.g. 3000m at 960kg/m^3)in the centre of glaciers exerts.

a pressure of about 27,600kPa on the lowest layer of ice. Since this lowest layer can only move sideways it flows under this immense pressure.

As thousands of winters add their load of snow to the top of the ice, the ice is kept moving outwards.

As summers become longer the sun melts more ice than is replaced during the winter. The net effect is that the outer edges of the ice mass as well as the top of the glacier melt. The runoff from these melting periods form rivers streaming from the ice mass. This water also helps form the lands by erosion near the ice and by depositing solids further downstream.

Erosion

Glaciers erode the land they encounter in several ways:

1) By simply bulldozing loose material in front of them;

2) By abrasive action (the underside of an ice mass is like a huge piece of sand paper);

3) By plucking pieces from the ground underneath;

4) By the scouring action of the streams formed by ice melting.

This erosion has been found to vary in depth from almost nothing to 18m. Generally, the ice mass gouges out the softer materials and leaves harder rock masses standing.

Since the softer rocks are more easily gouged out by the ice, they tend to form basins where lakes form. The Great Lakes are an example of this.

Deposition

As the ice of a glacier retreats (melts) it drops material it has carried. The material that was being pushed along in front is left as a ridge. If the ice advances and then retreats several times, a succession of ridges is formed. When ice melts without advancing again, a fairly level plain of "till" is left. This generally consists of boulders, sand, silt and clay all intermixed.

The streams of melt water flowing out from glaciers form sand and gravel ridges which follow the winding course of the streams under the ice. These, when they are exposed by the melting ice, are called "eskers".

The streams also carry silt and clay which deposit in lakes into which these streams flow. It is possible to find clays which are in distinct layers with silt layers alternating. The thickness of these layers varies from 0.8mm to 150mm.

Another type of deposit is due to wind action. As the melting glacier exposes more and more fine materials, some of these are picked up by the wind and form sand dunes and "loess" deposits. Loess deposits are very fine grained silt deposits. Two of their characteristics are high permeability and the ability to stand up with near vertical banks.

SOIL CLASSIFICATION

General

Soils are generally classified into groups according to their grain size. For convenience, particles larger than 75 mm in diameter are excluded from this grouping. The classes are as follows:

Coarse gravel	-	75 mm to 18 mm
Fine gravel	-	18 mm to 6 mm
Coarse sand	-	6 mm to 2.5 mm
Medium sand	-	2.5 mm to 0.6 mm
Fine sand	-	0.6 mm to 0.13 mm
Silt	-	0.13 mm to 0.05 mm
Clay	-	less than 0.05 mm

The above divisions are not exact. The characteristics of a soil are dictated not only by grain size but also by grain shape, water content and air content. An example of this is what is commonly called "rock flour". The grain size is that of clay. However, the characterics of rock flour are those of a silt.

Since it is relatively rare to find a soil in its natural state that is composed of only one grain size,

the properties of soils generally are dictated by the effects of the various components of that soil. The following will attempt to explain the behaviour of some common soil types.

Sand and Gravel

Both sand and gravel have essentially the same engineering properties. Sand or gravels that are "well-graded" (i.e. sand or gravel that has its sizes vary over the entire sand or gravel range) are stable material, are pervious, easily compacted, little effected by moisture and are not subject to frost action. As sand becomes finer and more uniform it approaches the characteristics of a silt with a corresponding decrease in permeability and a reduction in stability in the presence of water.

Silt and Clay

General

Fines in soils have an important effect on its behaviour. As little as 10 per cent of the particles smaller than 0.13 mm in a sand or gravel may make it virtually impervious. Serious frost heaving may occur.

Soils whose major component are silt or clay are the most worrisome to those concerned with construction. These materials exhibit marked changes in physical properties with the addition (or subtraction) of water. A hard dry clay for example may be a good foundation material. However, when it becomes wet it may turn into a swamp.

Many fine soils shrink on drying and expand when wet. This may adversely effect structures built on

them. The difference between an undisturbed soil and a re-handled soil (previously disturbed by excavation, etc.) may be radical.

Silts

Silts are non-plastic fines. They are by nature unstable in the presence of water. They are fairly impervious, difficult to compact and are very susceptible to frost heaving. Unlike clays, silts will change volume with a change in shape and have a tendency to become unstable ("quick") when saturated.

Clays

Clays are plastic fines (i.e. they retain their volume with change in shape). They have low resistance to deformation when wet, but dry into hard cohesive masses. Clays are practically impervious, difficult to compact and near impossible to drain.

> Note: Silts are quite different from clays but due to a similarity of appearance they often have been mistaken one for the other, sometimes with unfortunate results.

SUBJECT:

CONSTRUCTION OF SEWERS
WATERMAINS AND ASSOCIATED FACILITIES

TOPIC: 4

ENVIRONMENTAL CONSIDERATIONS

OBJECTIVES:

The Trainee will be able to:

1. Better understand the Environmental Assessment Act, 1975.

2. Recall why certain environmental control procedures are followed during construction.

3. Describe specific procedures for environmental control.

ENVIRONMENTAL CONSIDERATIONS

GENERAL

In recent years, an aroused public interest in environmental protection has manifested itself in response to such large-scale projects as nuclear power plants, sewers, sewage treatment plants, freeways, pipelines, river diversions, new towns and international airports. The public in many instances has objected to projects on grounds such as personal disruption, economic disadvantages or infringement of property rights. Environmental concern was never much more than an underlying or latent issue in these objections. Now things have changed and environmental issues have assumed greater importance. There is growing public support for the proposition that environmental considerations are an essential input at an early stage in project planning rather than as an after-thought.

As a result of this increased public awareness and desire for the protection of the environment, the Ontario Ministry of the Environment introduced the Environmental Assessment Act, 1975 in the legislature on March 24, 1975. Subsequently it received third reading on July 14, 1975 and certain sections of the Act, especially those pertaining to the creation of the Environmental Assessment Board, were proclaimed early in 1976. All the remaining portions of this legislation were proclaimed on October 20, 1976.

ENVIRONMENTAL ASSESSMENT ACT 1975

Purpose

What this legislation does in effect is require the proponent of a project designated by regulations to submit to the Minister of the Environment for his approval,

an environmental assessment of the undertaking. No other approvals can be given by any provincial or municipal agency until Ministerial approval of this document has been received. If the need for the project can be firmly established and the assessment study can ensure minimal environmental degradation through proposed mitigation techniques, etc., then the project would likely receive approval. Thus the emphasis for environmental control has been switched from the abatement approach of the Environmental Protection and The Ontario Water Resources Acts to one of avoiding impacts through comprehensive planning. This will result in reduced cost to the public and the proponent and more effective protection of the environment.

Approval Process

The environmental assessment approval process as set out under the Act requires the proponent to first of all determine through consultation with the Ministry of the Environment whether his particular project falls within the scope of the Act. For Government ministries and agencies, this designation has already been decided upon by regulation.

Private sector projects are not subject to the Act unless they are specifically designated by the Provincial Government.

Municipal projects are expected to be designated by regulation in the near future.

Environmental Assessment Types

There are two types of environmental assessments which can be prepared - individual and class.

For those projects which are considered to have major environmental consequences, individual environmental assessment studies are prepared.

For those smaller projects that have minor environmental effects and are frequently occurring, class environmental documents can be prepared. What this means in effect is that each project within a class will not be subject to individual reports or hearings provided they are planned and implemented in accordance with certain mandatory environmental procedures. A typical class or category of projects would be all expansions to existing sewage treatment facilities.

The environmental assessment reports are circulated to and commented on by all government agencies considered to have an official interest in the projects as well as by interested public. Then, based on the review-comments, the Minister of the Environment causes a Government Review to be prepared. This review outlines the preliminary position of the Government with respect to the project. The public is then given an opportunity to respond to the Environmental Assessment and the Government Review, and to request a public hearing. If a hearing is not required, the Minister of the Environment with the approval of Cabinet decides on the acceptability of the document and approval of the project. If a hearing is held these decisions are made by the Environmental Assessment Board.

A legal requirement of the approval to proceed issued by the Minister or the Environmental Assessment Board is that the proponent is bound to carry out his mitigation techniques in accordance with what has been outlined in the environmental assessment document and the conditions of approval. This means that these techniques

must be outlined in the tender documents and the plan and profile drawings by the engineering consultants so that every contractor bidding on the work is aware it represents part of the bid package. In this way there is no confusion about work to be done and the contractor cannot later submit claims for additional payment for certain mitigation measures carried out in the course of the contract.

ENVIRONMENTAL CONTROL PROCEDURES

It is very important that the site inspector ensures that the methods to mitigate or avoid environmental impacts identified as being significant in the report and specified in the Contract Documents are put into practice. Because of the sometimes complex nature of the mitigation procedures and the respective lack of practical knowledge by the inspector, the following paragraphs are designed to enlighten him so that these measures can be conducted as called for in the specifications. This then ensures that those potential environmental impacts identified in the planning stage are properly dealt with in the construction stage.

Construction Equipment Maintenance

The inspector must see that precautions are taken to prevent the spillage of oils, fuels and other waste solutions generated during equipment maintenace. He has to familiarize himself with the procedures required for the rapid clean-up of spillages that might occur as well as the satisfactory disposal of the spilled material.

Refuelling and maintenance of equipment cannot be allowed in or adjacent to watercourses but must be performed at remote storage areas. If properly prepared, suitable refuelling and maintenance areas will have been defined at the planning stage.

Slippage Areas

Normally, the pipe alignments are selected to give the foot of steep valley walls, which are prone to slippage, as wide a clearance as possible. In such critical areas, detailed construction procedures will have to be followed. These would include what areas require stablization and what material is considered suitable for that application. It should be the job of the inspector to make sure that those slopes which he considers steep and prone to slippage are given as wide a berth as possible.

Right-of-Way

The construction right-of-way is designed to minimize the areas of disturbance. The inspector has to see that construction equipment is kept within this designated right-of-way by utilizing stake lines or fencing if necessary. Haul routes, parking areas and so forth must be restricted and only the minimum number of routes absolutely necessary should be permitted up valley walls. Not all areas of a particular route will require a right-of-way width of 25 to 30m. In the vicinity of areas designated as critical (i.e. stream crossings, mature tree stands, etc.) the inspector must limit the right-of-way in order to reduce adverse effects. Such limitations may necessitate a change in excavation procedures near these critical areas. Once discussions have been held with representatives of facilities or areas considered as sensitive such as golf courses, hospital zones or public recreation areas, the inspector must ensure that the most suitable alignments, construction schedules, restoration procedures, access routes, easement widths, etc. are followed.

Clearing of Vegetation

Prior to any clearing of vegetation, the routing will have been examined to determine if it is necessary to remove all vegetation along the right-of-way. For example, all trees need not be removed if the pruning of low branches will suffice. The inspector must see that all those trees left standing have fencing placed around the drip line. Vegetation should not be removed prematurely from the route but should only be cleared in advance of the immediate construction phase. Restoration of vegetation including interim measures cannot be left as a final operation to be undertaken upon completion of the trunk line but effected in stages as soon possible after clearing. Trees that are removed are usually replaced on a one for one basis where it is feasible. Prior consultation will have predetermined what trees should be marked for removal or what minimum diameter at breast height (D.B.H.) is suitable in order that trees should remain. The inspector must make sure these instructions on the contract drawings are followed to the letter.

Stockpiling of Excavated Material

The inspector must familiarize himself with procedures established for the stockpiling of top soil, excess excavated material, bouldery remnants, etc. Methods presently in use include interim stabilization and covering of excavated material with plastic sheeting in critical areas. Depending upon the length of time a stockpile is to remain and upon the season, the excavated material might require a perimeter ditch as well as a settling area. As a general rule, stockpiling should not be located adjacent to watercourses. At the completion of construction, the inspector must see that any excess material is removed and placed in a more appropriate predetermined location - this does not include flood plain areas proximal to the construction. Alternatively, the site engineer may wish to establish better contour and grades in particular areas to help restore natural site drainage.

Sediment Control and Erosion

Prior to construction, procedures will have been established for the minimization of erosion and control of any erosion which might occur during construction. The inspector must see that erosion is minimized by strict adherence to recommendations made in the slippage, clearing of vegetation, stockpiling, stream crossing and restoration sections of the Contract Documents. Silt traps and ditching devices along the construction route as indicated in the plans are designed to help control erosion that occurs (especially during storm periods). The inspector should ensure that any control device called for in the specifications is installed prior to construction activities. He will determine if the silt traps need to be re-excavated (and in such a manner which will not introduce sediments to the watercourses) in order to maintain their efficiency.

Placement of Soil in Woodlots

Frequently soil material excavated from a right-of-way is placed on either or both sides of it. The access to woodlots along rights-of-way should be restricted by the use of snow fence and intensive educational programs. If trees are to be saved, soils should not be piled around root systems nor should heavy equipment be allowed to pass close to the trunk. Also, overhanging branches should be removed prior to the movement of mechanized vehicles along the right-of-way. Where damage does occur, surgeon paint should be applied.

Stream Crossings

Stream crossings and the amount of stream bank modification should be kept to a minimum. Necessary crossings should be at right-angles or as close to right angles as possible. The inspector must ensure that the stream crossings are conducted according to the contract specifications. Such features as diversion culverts and fill material must be suitable for that application and properly positioned. Regarding the crossing itself, the clearcut right-of-way of the approach should be limited. The number of points that heavy equipment can cross the river should be restricted and at no time should the stream bed be used a route. Backfill must be satisfactory to prevent erosion and washout. The actual crossing should be planned to coincide with low flow periods and the work staged to minimize the time of soil exposure.

Discharge to a Watercourse

Any water that is collected or removed from trenches in the construction zone must not be discharged directly into a watercourse until adequate treatment has been provided to remove suspended silt, clay and other contaminants. If treatment prior to discharge in to a watercourse is not considered practical, consideration should be given to another means of disposal such as discharging on grassy areas sufficiently remote from the site.

Groundwater

On certain projects, the inspector may have to deal with a shallow perched water table. Where a pipe, especially a sewer, intersects a shallow perched water table, extra

precautions are necessary to ensure that the sewer is impermeable in order to minimize the possible effects of leakage and groundwater contamination. Water pumped out for purposes of trench dewatering should not be discharged directly to watercourses as above. Also, the inspector must ensure that there is minimum disturbance of areas of groundwater seepage, particularly near steep slopes.

Dust Control

Associated with most construction projects is the problem of dust control. Depending upon the time of the year and the weather conditions, conditions may become quite an annoyance. The inspector should exercise his judgement in determining whether some control measure is necessary and what method might be most appropriate in a particular situation. A general rule of thumb to follow is that if the construction is in an urban area particularly in the summer, periodic spraying with water or the application of calcium chloride is good preventative medicine.

Hydrostatic Testing

Water used in the hydrostatic testing of the pipeline should not be discharged directly to watercourses. It is recommended that the discharge be buffered with a holding lagoon or alternatively a discharge pipe and diffuser properly positioned in relation to the receiving waters. These decisions will have been made prior to the testing so that the inspector can enforce the specified method. The rate of discharge to and from the holding lagoon to the watercourse must be regulated in order to preclude erosion and sedimentation in the watercourse. Water containing suspended silt, clay and other contaminants should not be discharged to the watercourse without adequate treatment.

Restoration

One of the most important aspects of any construction project is the site restoration. Once the pipe is in the ground people no longer are concerned about it but they will become concerned very quickly if some feature above ground is not returned to its original state. Prior to construction, procedures will have been defined for the interim (i.e. mulching, use of netting, seeding of grasses) and long-term rehabilitation (replacement of vegetation) of areas disrupted by the construction. As far as possible, disturbed terrain should be returned to its original contours. However the drainage in certain areas can perhaps be improved upon where considered desirable. Other landscaping features such as tree replanting must be carried out in accordance with the specifications and the responsibility rests with the inspector to see that the work is conducted satisfactorily. Follow-up procedures at a later date can assess the effectiveness of the restoration and improve areas of deterioration and inefficient restoration. For example, additional work may be required to remove the effects of settling.

These and the many related aspects of site rehabilitation are discussed at some length in a later section on "Restoration" in this manual.

SUBJECT:

CONSTRUCTION OF SEWERS
WATERMAINS AND ASSOCIATED FACILITIES

TOPIC: 5
CONSTRUCTION SAFETY

OBJECTIVES:

The Trainee will be able to:-

1. Recall the purpose of the Construction Safety Act.

2. Interpret and implement the Construction Safety Act 1973 and Regulation 419/73 insofar as safe construction practices are concerned.

3. Differentiate between the duties of the Owner's Inspector and the Inspector of the Ministry of Labour.

CONSTRUCTION SAFETY

GENERAL

Regardless of laws or apparent degree of responsibility, safety on a construction site is everybody's business. In general terms, it can be said that contractors are becoming more conscious of the economic benefits that can be a by-product of good safety practises, along with the obvious benefits to the workmen themselves. Construction management and personnel are governed in their actions by the references to safety in the contract documents, and by The Construction Safety Act 1973 and Ontario Regulations 419/73, which provides protection for personnel by requiring certain standards of conduct of the contracting company and of the equipment on the project.

It should be noted that the four major causes of death and disability are:

1. cave-ins
2. hydro contacts
3. unguarded power tools
4. falls between levels.

One must consider that the Regulation exists due to obvious omissions or neglect to perform some obvious duty and really points up the fact that an Owner's Inspector should be aware at all times what is, or is not, being done.

This Topic is designed to assist the Owner's Inspector.

1. In becoming more familiar with the safety acts in force affecting trench work.

2. To give some direction as to action which should be taken to ensure the safety of personnel on his project.

3. To motivate each Owner's Inspector to complete a study of the Act and Regulation.

Any queries can be directed to the Ministry of Labour at any time from the address given at the back of the green book.

When the Owner's Inspector is given the specifications for a project, he will find clauses indicating that the contractor is to comply with the requirements of The Act and Regulation which are the minimum requirements with regard to safety on the project. A portion of the General Clauses will probably read as follows:

Requirements of the Local
Construction Safety Inspector

Immediately after the successful ***tenderer*** *has been notified that his tender has been recommended to the Owner for acceptance, if the trench exceeds 25' in width he shall prepare drawings, showing any shoring or sheathing details, etc., which will be utilized by him during the construction of the work and submit same as soon as possible to the Ministry of Labour, Construction Safety Branch, for their information and possible objection.*

It is necessary that these required drawings are in the Safety Inspector's hands at least two or three weeks before construction starts. Following up this request will prevent delays in permission to start construction.

Owner's Inspector and Inspection

In particular, but without limiting the powers of the Owner's Inspector, orders given by the Owner's Inspector relating to the quality of material or workmanship or in respect of safety or public conveniences must at once be obeyed by the Contractor. The Owner's Inspector shall have the power to suspend any workman for incompetency, drunkenness, negligence or disregard of orders and the Contractor shall ensure that any workman so suspended is forthwith removed from the site.

Public Convenience and Safety

If at any time the Engineer or his authorized representative considers the works to be unsafe he may order the Contractor to take measures forthwith to ensure adequate safety. Should the Contractor fail to take adequate measures, the Engineer or his representative may order the work to cease until such measures have been taken. The Contractor shall not be entitled to additional payment for, or an extension of time for the performance of the Contract by reason of, such safety measures. The fact that the Engineer or his representative has ordered or has failed to order additional safety measures shall not relieve the Contractor of responsibility for the adequacy of the safety measures taken.

The minimum acceptable quality of safety on a project is contained in The Construction Safety Act and Regulation. Copies of this Act and Regulation should be in the Owner's Inspector's site office. The Law requires the Contractor to have a copy of the Act and Regulation on the project at all times.

RESPONSIBILITIES

The administration and enforcement of the Act and Regulation described in this Topic is that of the Ministry of Labour, under the Director of the Construction Safety Branch and his appointed Inspectors. These Inspectors make periodic visits to all construction projects under their supervision, and it is their responsibility to deal directly with the contractor. They will leave written instructions with the contractor for any infractions which have to be corrected, and the instructions are to be acted on without delay.

The Owner's Inspector may read through the Act and feel that he has no responsibility concerning enforcement of the Act and Regulations. The contract includes Construction Safety Act, as noted at the beginning, and so the Owner's Inspector has some responsibility to his superior, and the owner. Familiarity with the Regulation will allow him to point out to the contractor any infractions which should be corrected. If the contractor neglects to take any action, and safety provisions are being contravened or ignored, then the Owner's Inspector must contact the proper authorities and request them to visit the site. If this is not done and an accident occurs, then the Owner's Inspector may find himself in an awkward situation, whereby he will not be able to hide behind the wording of the Act.

The Owner's Inspector should realize that he is in a position to stand back from the action and take time to notice things that should or should not be done. The contractor, on the other hand, is a very busy person trying to complete a contract, and may quite honestly fail to notice safety practices which should be improved.

This part of the work can be a team effort, but there should be no hesitation in calling Provincial Inspectors if there is continuing abuse of safety practices.

CONSTRUCTION SAFETY ACT

The Act itself is concerned with the assigning of responsibilities to all engaged in construction and those appointed by the Province to administer the Act. It outlines the actions that the Owner's Inspector should take on finding contraventions of the Act, or after an accident has happened.

1. Sections 1 to 13 define terms which apply throughout the Act and Regulation. These should be fully understood, e.g. the difference between a trench and an excavation.

2. Sections 14 to 24 of the Act state the type of safety measures any contractor, supplier, organization or individual must keep in force. It should be noted that the word "ensure" used in these sections places strict liability on all individuals.

3. Section 25 discusses action that must be taken following serious injury.

4. Section 26 gives actions which may be taken by the Court following a contravention of the Act.

5. Section 30 indicates the procedure to be taken by the Contractor following an accident, if the employer is not required to report to an Inspector as outlined in Section 25.

6. Section 31 summarizes the details covered in the Regulation.

The important thing to be remembered by the Owner's Inspectors, and all working on the project, is that the Ministry Inspectors have wide powers under the Act, and it is to them that Owner's Inspectors must turn if contractors

will not listen to reasonable requests. There are certain procedures to be followed after an accident occurs and the Owner's Inspector should, for his own information, and in a quiet way, ensure that these are being followed.

REGULATION 419/73

General

The Regulation made under authority of Section 31 of the Act details safety requirements for all phases of construction work. An Owner's Inspector need not be overwhelmed by the fact that the Regulation includes a General Section and five parts of some 289 sections. At the same time, it should be realized that there are general safety rules as well as those concerned particularly with trench excavation, and these sections should be read until the Owner's Inspector is satisfied that he is familiar with all that apply to the project to which he has been assigned.

General, Section 1

The General Section, Section 1, interprets common terms found throughout the Regulation and supplements the definitions included in Section 1 of the Act.

Part I, Sections 2-154

Part I of the Regulation covers subjects which are common to all projects and, therefore, has application to all projects. It deals with safety measures related to such subjects as:

1. What a contractor shall do before commencing work and during the continuance of work on a project.

2. Duties of the superintendent of a project.

3. Public way protection.

4. Traffic control.

5. Personal protective clothing equipment and devices.

6. Sanitation

7. Fire protection, electrical supply and temporary heat.

8. Explosives

9. Construction equipment and explosives.

10. Ladders, platforms, ramps and runways.

11. Guardrails and scaffolds.

Some of the more important sections are:-

Notice of Accidental Occurrences, Section 8

The Owner's Inspector should offer any assistance possible to the contractor. He should satisfy himself that the contractor has notified the Ministry of Labour . He should notify his supervisor by telephone as soon as possible and be sure that his daily records contain as much information as possible regarding the accident.

Traffic Control, Sections 13-17

Proper control of vehicles and pedestrians past a construction site is a responsibility of the Owner's Inspector.

He should be provided with any local regulation regarding such control which would be used, together with the specifications. This would include such details as:

a. Properly dressed, trained and equipped flagmen.

b. Adequate delineators to channel the flow of traffic.

c. Adequate flasher barricades and traffic signs. Continuous servicing of barricades, particularly during the night hours.

d. Snow fencing or other required fencing along the trench excavation to separate the working area from the traffic flow.

Personal Equipment - Sections 30-32

Safety hats and safety shoes must be worn at all times. Safety glasses are required when doing close work which could result in eye damage.

Housekeeping - Sections 42-58

Good housekeeping near the trench is important to prevent any objects from accidentally falling on men in the trench. It is good practice to maintain all parts of the work in a tidy condition. It can contribute much to the reduction of accidents on the project and also provides a more efficient and economical operation.

Not all the sections noted above may apply to trench work but can give food for thought.

Overhead Wires - Section 72

Section 72 limits the distance between any object, including a crane boom, and an electric power line of more than 750 volts, to ten feet, as shown in the table included.

There are exceptions to this, such as electric supply disconnected, electric lines properly insulated, or modifications to the equipment to prevent an accident. Treat all power lines as if more than 750 volts unless informed otherwise by the Owner of the power line. (Hydro, P.U.C., etc.)

Explosives - Sections 104 to 113

These sections of the Regulation detail requirements when explosives are used on the job. These sections by no means cover all the regulations with respect to the use of explosives. There may be in addition, local by-laws regarding use of explosives. If the use of explosives is anticipated on a project, the various regulations will be specified, probably as follows:

"The supplying, hauling, handling and storing of all explosives and accessories shall be done in accordance with the rules and regulations of the Explosive Division, Department of Energy, Mines and Resources, Ottawa; The Construction Safety Act of the Province of Ontario and Ontario Regulation 419/73."

The Owner's Inspector should receive from his superior the duties required of him with respect to this specialized operation.

Part II, Sections 155 to 217

General

This section of the Regulation deals with tunnels,

caissons and similar work, and would apply on a sewer or water main contract where tunnel work was called for, regardless of the length of the tunnel.

This would not be the type of work an Owner's sewer or water main Inspector would normally encounter, and it is mentioned here briefly in order that the Owner's Inspector would know such sections of the Regulation exist.

Work Covered - Construction of Shafts, Tunnels, Caissons and Coffer Dams

The Owner's Inspector should satisfy himself that a set of drawings showing details of shoring, bracing, lagging, etc., signed by a professional engineer, where required by the Ministry of Labour, is on the site before work is commenced.

Safety Measures and Equipment

These requirements are similar to those for trench work, with additional requirements regarding ventilation, bracing, special protective clothing, if necessary.

Shafts

Minimum dimensions are 8'-0" diameter or 5 feet other than cylindrical with a minimum area of 50 square feet.

The shaft shall be guarded at the top, and emphasis is made on hoisting equipment, ladder and landing arrangements and communications between the top and bottom of the shaft and the top of the shaft and tunnel face by telephone or other approved means. All shafts over 100 feet deep shall have a hoist for personnel, details of which are given in the Regulation, including signalling and maintenance.

Lighting

Lighting, ventilation and communications are covered in the Regulation.

Fire Prevention

Fire prevention is mentioned in some detail. This is always a danger in tunnel work, in particular in compressed air, and requires constant surveillance.

Part III, Sections 218-270

This Part of the Regulation deals with work in compressed air.

This is specialized work requiring that a person be certified medically fit for such work. Usually the Owner's Inspector would be examined by the physician engaged by the Contractor. Sections 254-265 cover the medical facilities which a contractor must provide.

Sections of particular importance are:

1.	Sections 223-241	Compressors for Air Supply
2.	Section 242	Communications
3.	Sections 244-250	Decompression Rates
4.	Section 251	Responsibilities of the Lock Tender
5.	Section 270	Notice to Public Authorities

Part IV, Sections 271 to 287

This Part of the Regulation deals with Trenches.

Side Slopes on Trenches - Section 273

This section of the Regulation calls for the shoring of trenches in excess of 4 feet in depth except where ground conditions permit sloping of the sides of the trench. The slope starts not more than 4 feet above the trench bottom and is cut back at a 45^{o} angle, or one foot vertical rise to one foot horizontal run. If the slope starts more than 4 feet from the bottom of the trench, then those vertical walls have to be properly shored.

Ladders - Section 275

This section requires that ladders or other means of egress be provided not more than 50 feet from any workman in the trench. Sections 116 to 123 describe ladder construction and use.

Loading Sides of Trench - Section 276

The Owner's Inspector will have to be aware of any excessive loading on the sides of the trench, such as:

a. Casting material from the trench too close to the edge.

b. Operating machinery too close to the edge.

c. Storing pipe or pipe bedding material too close to the edge.

Barricades - Section 277

This section deals with fences, barricades, etc., around work.

This is important from the viewpoint of public relations, as well as for protection of workmen. There is sometimes a tendency to concentrate on the section of trench under construction, and forget about excavations which are left behind for chambers, manholes, etc.

The Owner's Inspector should visit all sections of the project after the day's work before leaving, to ensure that the Contractor has adequately barricaded and lighted any areas requiring protection. Criminal charges may result from the failure to barricade an excavation.

Sheathing and Shoring - Sections 278 to 287

These sections are very important and will probably be referred to more than any other during the course of any project. However, the Owner's Inspector should also be familiar with Section 272 - Definitions and Section 274 - Support Systems which indicates when supports are to be installed and withdrawn.

Section 278 gives the requirements dealing with excavations which apply to trenches.

Section 279 shows trench limits for the use of the tables (Sections 282 to 287) included in the Regulation.

Section 280 gives the procedure to be followed with support for trenches having dimensions in excess of those specified in Section 279.

It is important that the Owner's Inspector satisfy himself that approved drawings are on the site before the particular equipment is used, and that the

equipment has been fabricated in accordance with the drawings. The prefabricated support system referred to in this section usually consists of a fabricated steel open-ended box which is dragged along the trench as the work proceeds.

Sections 284 to 286 should be read carefully, as at first glance it may seem confusing due to soil numbering, table numbering, column numbering, etc. It is suggested that the Owner's Inspector make himself familiar with the Regulation and the tables included. Section 39 should also be studied.

When faced with a situation requiring use of the table, it is wise to go over the job conditions and materials required two or three times before confronting the contractor, so that you are satisfied he is not being asked to do something unreasonable. It should be noted that, although the description of the types of soil in Section 272 is made reasonably clear, the Owner's Inspector may still find some difficulty in obtaining the agreement of the contractor in a particular situation.

It should be noted that Section 287 allows the use of trench jacks in place of timber struts, providing that the jack strength exceeds that of the strut.

SUBJECT:

CONSTRUCTION OF SEWERS
WATERMAINS AND ASSOCIATED FACILITIES

TOPIC: 6

SANITARY AND STORM SEWERS

OBJECTIVES:

Trainee will be able to:

1. Recall the purpose of:
   a. A sanitary Sewer System
   b. A Storm Sewer System

2. Discuss as related to flow in sewers and to sewer construction:
   a. Grade and Alignment
   b. Manholes
   c. Complex Sewer Structures
   d. House Service Connections
   e. Catch Basins

3. Recall important points that should be considered during the inspection of a sewer construction project.

SANITARY AND STORM SEWERS

GENERAL ASPECTS

The purpose of a sanitary sewer system is to collect flow from all points of a developed catchment area and transport it to a treatment facility. The design flow for a sewer is calculated from the population density or number of people per hectare in the area served. The design flow calculated per hectare will vary depending on the use of the land, i.e. residential, commercial, industrial.

The purpose of a storm sewer system is to remove storm water rapidly and effectively and direct this water to a suitable outlet, usually a creek, river or lake. The design flow for a storm sewer is calculated from the run-off produced in the catchment area served by the sewer from a storm of a pre-determined intensity. The design flow will vary in quantity depending on the nature of the ground cover in the catchment area. Parking lots give almost instantaneous run-off, whereas grassy areas will absorb much of the rainfall.

The hydraulic elements of sewers include the determination of the sizes, depths, shapes and materials of the proposed construction.

GRADE AND ALIGNMENT

Sewers must be laid to line and grade and remain on line and grade to ensure efficient operation and avoid unnecessary maintenance and general operating problems. This is usually accomplished by using grade stakes to which batter boards and string lines are set.

Local service sanitary sewers are usually located in the centre of the street permitting a symmetrical arrangement for the private drain connections from the houses serviced by the sewer. These sewers must be deep enough to allow each connection to be laid at a proper grade and are themselves laid at a grade which will ensure that the sewage flows at a specified minimum velocity in times of low flow. The minimum velocity is that calculated to ensure transportation of all matter in the sewage at all times.

Local storm sewers are generally larger than the sanitary and need not be laid at such a depth as they generally collect the flow from catch basins. Their size depends on the size of storm setting the design criteria.

In both cases, the local sewers carry their flows into larger collector sewers which, in turn, pass the flow into interceptor sewers and thence to the treatment facility or point of discharge. These larger sewers are still laid in open cut but may be driven in tunnel if large enough or if dictated by economics or other considerations.

Contractors will generally use a transit to keep the pipes on line and grade. Often a laser beam is used which is set in the downstream manhole and projects through the pipe to a target placed in the bell of the pipe being set. This provides for very rapid progress of the work. Some contractors who have used this method claim to have achieved at least twice their daily production. Lasers are very common in tunnel work, especially where a mining machine is being used.

Bedding the pipe and backfilling the trench are of equal importance to line and grade. The bedding must be placed on firm undisturbed ground and compacted before the pipe is placed on it to ensure that the pipe does not settle

after backfilling. The first stage of the backfilling procedure is the placing and compacting of suitable material around and at least 300 mm above the pipe. This is required to ensure that the walls of the pipe are supported to the sides of the trench. When a pipe is laid in such a well-supported manner it will be structurally capable of carrying the remaining backfill dead loads and surface live loads. It will not be displaced during backfilling, it will be stable in the event of excavation adjacent to it at a later date. When completed, a good job will look like a gun barrel.

MANHOLES

One of the most important and most common structures found in both storm and sanitary sewers is the manhole. Manholes are placed at specified locations for cleaning and inspection purposes, at all changes in grade, changes in direction, changes in pipe size or variation in quantity of flow.

It is common practice to have a manhole at the upstream end of a sewer for convenience in flushing and cleaning and in the event of a future extension of the sewer. The recommended distances between manholes on a straight run is as follows:

1. 90 m for sewers 375 mm diameter or less
2. 120 m for sewers 450 to 750 mm diameter
3. for sewers greater than 750 mm diameter the spacing may be increased especially where sewers are big enough where a man can actually walk through. The spacing,

however, also depends on the cleaning equipment which the municipality has. If modern and efficient cleaning equipment is available in the municipality then the manhole spacing may be greater than a similar municipality which might have poor cleaning equipment.

Manhole spacing is governed by grades available. If flat grades are necessary then manholes should not be spaced too far apart since blockages are more likely than if good sewer grades are possible. At the other extreme, sewers going down steep hills may require "drop" manholes, closely spaced, to dissipate energy.

Manholes can be poured-in-place or precast and be designed as a drop manhole if a drop in excess of 1m occurs between any invert and the lowest invert in the manhole. The size of the manhole is usually determined by the size of the largest pipe entering the manhole but seldom are poured-in-place manholes less than 1200 mm square and precast manholes less than 1200 mm in diameter. Deep manholes will have safety gratings placed at suitable vertical distances, maximum 5m. These gratings are hinged to ensure that they stay in place but can be lifted to allow removal of foreign objects from the sewer below.

Many municipalities have standard details for manholes, the types of sealant acceptable in precast manholes and recommended locations for items such as step-irons. Aluminum ladders are preferable to step-irons but the first and last rungs must be located near to the cover at the surface and the benching at the bottom and the ladder located in the manhole in a position that will not interfere with sewage flow. Benching is an important part of the manhole as lack of it or incorrectly shaped benching causes head losses and sedimentation. Benching should also be sloped to

ensure cleaning of deposits from high flow occurrences.

Excavations for manholes must be properly supported to maintain stability of the surrounding ground. This will prevent possible displacement of the manhole after backfilling, especially in the case of deep manholes. The manhole must sit on a solid foundation to prevent settlement of any kind. The pipes entering the manhole will have joints placed close to the outside face of the manhole to provide some flexibility while the ground consolidates after backfilling. Backfilling should be done in lifts to permit good compaction as only too often road surfaces settle around the manhole cover as traffic compacts the backfilled material. All manholes should have corbelling to permit variation of elevation of the manhole cover if required due to street re-design. The drop pipe in a drop manhole should be surrounded with concrete poured with the manhole walls to ensure a homogenous construction.

COMPLEX SEWER STRUCTURES

Complex structures are included in certain sewer systems. Vortex shafts can be used to transfer sanitary sewage from collector sewers to an interceptor sewer. Drop shafts can be used for the same purpose in a storm sewer system. Such structures are designed with energy dissipating features. A vortex chamber has a stilling basin ahead of the drop shaft as the flow must enter the shaft in a specific manner. A drop shaft will have a submerged outlet or a break platform or a dissipation block.

Storm sewer systems have outfalls to lakes and rivers. Often these are underwater as such a design prevents problems with freezing or bank erosion. Outfall structures above water level must have safety gratings to prevent illegal entry, gabions or some form of bank protection, some form of energy dissipation feature, and a pleasing

appearance to the surrounding neighbourhood.

HOUSE SERVICE CONNECTIONS

The general purpose of constructing a sewer is to allow connections to be made to it from abutting properties. The flow characteristics in the sewer can be affected by the manner in which connections are allowed to be made and the number and relative size of connections made. Wherever possible, factory-made tee junctions should be installed at the time of original construction and the designer should make every effort to anticipate the number of connections required. In excessively deep sewers, it is quite important that risers be installed at the time of construction and brought to a usable depth below finished grade. Nowadays storm and sanitary systems are usually separate and it is imperative that a method be devised to make sure that private drain contractors know the difference between the storm and sanitary connection lines and are made to realize the importance of connecting properly. In spite of regulations and inspection, there is an alarming amount of storm water entering into the sanitary sewers. No amount of careful design can affect poor control over use of connections. On well-inspected sewer construction, sewers are adequately tight against infiltration, yet each new sanitary sewer, after private connections are made, has a marked increase in flow rates during and immediately after a rain storm. Close supervision of construction of house service connections is necessary and desirable.

CATCH BASINS

One of the important units in a storm sewer system is the catch basin. Regardless of the adequacy of the

underground sewer system, proper drainage cannot result unless storm water is quickly and efficiently collected and passed into that system. The purpose of the catch basin is to drain away surplus water from a road allowance or parking lot. Generally, catch basins are installed at intervals of 75 to 90 m on both sides of a street.

Until recently, it was customary for a designer to show that standard catch basins were to be installed at various points. Today, there are several types of catch basins. These variations developed from observing problems in the field and the designer should consider the conditions likely to prevail and choose the type of catch basin that will best suit the given situation.

The most widely used storm sewer inlets are as follows:

(a) Gutter inlet - a standard catch basin sitting in a slight depression in the roadway gutter.

(b) Arch-back inlet - a catch basin inlet composed of both curb and gutter openings acting as an integrated unit.

(c) Ditch inlet - an oversized catch basin with its frame usually inclined at 30-45^{o}.

Catch basins with throttling devices can be purchased for use in areas designated as storm storage areas.

Catch basins are usually constructed with a 300 to 450 mm sump in the bottom which collects grit, leaves and other debris which otherwise would enter the sewer system. Catch basins should be cleaned regularly to prevent sewer blockages.

It has been shown that lack of catch basin cleaning leads to an increase in the amount of pollution passing through the storm sewer system.

MATERIALS USED IN SEWER CONSTRUCTION

The following factors must be considered prior to selection of the sewer construction materials:

1. Flow characteristics.
2. Life expectancy.
3. Resistance to scour or sulphide build-up.
4. Resistance to acids, alkalis and solvents.
5. Ease of handling and installation.
6. Structural strength.
7. Type of joint.
8. Availability of pipe and size variations.

The four most commonly used materials are plain or reinforced concrete pipe, asbestos cement pipe, vitrified clay pipe, and poly-vinyl chloride pipe.

CONSTRUCTION CONSIDERATIONS

There are certain important points that an inspector should pay particular attention to during construction. Some of these are as follows:

1. The bedding must be to grade and a hole dug out for the bell to prevent bridging of the pipe from bell to bell on the bedding.

2. Final adjustments may be made to the pipe grade by placing pieces of wood under the bell or front edge of spigot piece but these must be removed when grade is set.

3. Ensure that materials are properly compacted around and over the pipe.

4. There should not be large boulders in the backfill.

5. Place concrete under inlet/outlet pipes between base of manhole and natural excavated ground or install a flexible joint within 300mm of the base of the manhole.

6. Ensure that there is proper connection of house services at the main sewer and a proper plug in the end of the service, especially where connecting to an older sewer. Careless or improper connections might block the passage of T.V. cameras, making full inspection impossible.

7. A very important duty of the inspector is to ensure that the joints are made properly whether they are hemp and mortar, confined 'O' ring or collar type in that the bell and spigots are in good shape, not damaged, and are perfectly round and fit properly.

8. Smaller pipes are usually put home by hand with a large bar. They must be fully driven home and not permitted to spring back. Larger pipes should be put home with a come-along operated from inside the pipe. In no case should the backhoe bucket be used to drive a pipe home.

SUBJECT:
CONSTRUCTION OF SEWERS
WATERMAINS AND ASSOCIATED
FACILITIES

TOPIC: 7

WATERMAINS

OBJECTIVES:

Trainee will be able to:

1. Recall the purpose of a watermain system.

2. Discuss in general terms the distribution system layout and alignment.

3. List watermain appurtenances and recall the purpose of each.

4. Recall important points that should be considered during the inspection of a watermain construction project.

WATERMAINS

GENERAL ASPECTS

A watermain system is designed to adequately satisfy the water requirements for some combination of domestic, commercial and industrial users as well as fire-fighting purposes. The system should be capable of satisfying the maximum demands placed upon it.

A watermain system is composed of three main parts:

1. Source plus treatment - lake, river or well plus necessary purification facility.

2. Transmission line from facility to distribution system.

3. Distribution system to customers.

SYSTEM LAYOUT AND ALIGNMENT

A water distribution system is generally divided into pressure zones. Each zone contains a network of pipes capable of transmitting water flows at the specified zone pressure. Generally, each zone will have a pumping station to overcome the line losses and maintain pressure, and a reservoir to balance the flows. The distribution system should have certain design features to reduce losses within it:

1. Minimize dead-ends by looping mains.

2. Interconnect the various pipelines forming the system at regular intervals - 350m or less.

3. Locate valves to minimize the area that would be deprived of water service in the event of a shut-down.

4. Space hydrants in accordance with the Canadian Underwriters' Association or the local fire department or at no more than 125 m intervals.

Many municipalities have standard street cross-sections which detail the location of a watermain in any one street. Generally, the watermain is located off the travelled portion of the roadway, in the boulevard, as this reduces installation costs and provides more insulation for the main as frost penetrates deeper beneath a travelled roadway. In the event that the street is a major thoroughfare or highway, the main will be located well off the pavement or even in adjacent property or streets as traffic disruption and road restoration are major considerations and better avoided.

The depth of cover can generally be kept to a minimum, for a watermain being a pressure conduit. Considerations required in this part of the design are the depth of frost penetration, the use of the main (continuous or otherwise), trench loading and proposed or future road grades. Generally, the minimum cover is 1.5 m.

In the case of trunk watermains, a plan has to be prepared which details the location of all utilities. This information permits a study of the street to determine whether or not there is space available for a new installation. Once it has been decided that such a route is feasible, drawings are prepared and submitted to all interested authorities or utilities for their information and general approval.

It is important that the watermain be laid to the horizontal and vertical alignments chosen in the design. As

a pressure conduit a watermain has to give way to storm and sanitary sewers, and their connections, and to major installations of other utilities such as underground hydro vaults or gas metering chambers which are also generally located off highways. Construction consideration has to be given to overhead wires and trees which are often close to or over the proposed route. Poor attention to alignment may cause air pockets to form in the main which cuts down the effective pipeline area. The inspector will notice that any watermain, large or small, has often many tight squeezes along its route caused by these existing conditions.

One of the benefits that a watermain possesses, being under pressure, is its inherent flexibility with regard to its alignment. Vertical shafts and tunnels can be incorporated to traverse valleys or steep slopes, roads and railways can be tunnelled, rivers can be crossed in open-cut or on piers, swamps or muskeg can be overcome by rafting or piling. In many cases a watermain project can be a challenge to the inspector.

WATERMAIN APPURTENANCES

A trunk watermain or watermain system requires various aids to allow efficient operation or control, generally termed valves and appurtenances. These are discussed below.

Control Valves

These are spaced to minimize the area that would be deprived of water service in the event of a line break or a planned or emergency shut-down.

Gate valves are generally used in distribution mains. It is common practice to install four valves at a four-way intersection and three valves at a three-way intersection. Valves would be spaced at a maximum distance of 150 m at other occasions but this will vary in accordance with the density of land use.

Butterfly valves are often used in trunk mains as they cause less pressure disturbance in opening or closing. These would be placed at zone changes, municipal boundaries or between major distribution main junctions. These are also used in distribution mains larger than 300 mm diameter.

The specifications should give the direction of valve opening which should be consistent with the bulk of valves presently in the system or as approved by the client. The size of operating nut or type of operator should also meet these requirements.

When a connection is required to an existing system, often a tapping sleeve will be used. A pressure tap consists of a tapping sleeve which is braced around the pipe to be cut into and a gate valve which is attached to the sleeve to prevent the water from the pressurized pipe escaping after the connecting hole is cut in the existing pipe. Pressure taps are most common for small diameter connections and not used for very large connections as the tee must be reinforced if the circular structure of the pipe is excessively reduced by a large diameter tee connection.

Air Relief Valves

A watermain can carry considerable amounts of air and water. This is not a serious problem in a system with many fire hydrants as these can be used to

relieve air build-up in the system from time to time. Smaller mains may have a copper blow-off pipe attached to the pipe controlled by a gate valve.

Trunk watermains require air relief valves. These valves are generally designed to operate automatically, permitting bleeding of air from the main whenever necessary. Air build-up will take place at a high-point in the system, as the velocity in the main will be at its lowest thereby allowing the air to gather at this high point. This can be considerable if the high point is located a long way from the reservoir if a gravity system or from the pump if a pressure system. If enough air collects without relief, a pressure block will form in the main severely disrupting supply.

In certain systems air valves can be installed which also act as vacuum valves. In this condition, the valve permits the flow of air into the line during draining of the line and the internal pressure reverts to atmospheric. This prevents a vacuum forming in the line and protects the system from collapse.

Drain Valves

Larger diameter watermains have drain valves installed at the lowest points of their alignment to permit draining of the main. The drain valves are gate valves generally placed on a tee to the side of the main, draining to a watercourse or other means of removal of the unwanted water.

Valve Chambers

These are generally provided for large valves which may have a handwheel for their operation or are electrically operated. The chambers may be poured-in-

place or formed with precast sections. In either case, the chamber should be large enough to permit easy access to the valve both for operation or removal. Large valves may require couplings to be placed in the pipe beside them in the chamber to permit removal of the valve.

Valve Boxes and Stems

These are used for smaller valves where it is necessary to provide access to the operating nut. This access is provided by use of a valve box and stem. The stem is a hollow cylinder that fits over the operating nut. The valve box is attached to the top of the stem and provides access from the ground surface. The stem and box assembly should be adjustable to permit adjustment with respect to roadwork.

Hydrant

Fire protection manuals suggest that hydrants be located so that no building is more than 120 m from a hydrant. Hydrants are equipped with a shut-off valve between the hydrant and the main. This facilitates the maintenance and replacement of hydrants without disturbance to the flow in the main.

Hydrants must be installed in a way to ensure that they do not move or that joint separation is caused by the water pressure. This is usually accomplished by the use of wooden or concrete thrust blocks at the base of the hydrant stand-pipe or by the use of hydrant anchor tees.

Service Connections

Service connections can be provided by the use of copper, cast iron, ductile iron, asbestos-cement or plastic pipe. The most common material used is copper, soft type K. The size more generally recommended is 20 mm diameter.

These services should be equipped with a corporation stop and a curb stop. The corporation stop is attached and threaded into the wall of the watermain. Consideration should be given to the thickness of the pipe wall and the tap size to ensure a serviceable, threaded connection. The corporation stop has a shut-off so that the stop may be set in the line under pressure and be subsequently opened for service. A corporation stop does not have a valve stem and a box.

The curb stop is normally situated at the property line and provides a shut off in the event that maintenance work is required on the private service. The curb stop consists of a valve, valve stem and box similar to that on a main line valve.

All copper water services should be installed with a vertical goose neck at the main to reduce the possibilities of ground settlement shearing the copper pipe from the corporation stop.

All plastic water services should have a horizontal goose neck.

Bends, Wyes and Tees

Bends, wyes and tees are known as specials and are integral parts of a distribution system. It is at these locations that unsupported thrusts can develop and must be counteracted in the design. The inspector should ensure that pipe alignments are accurate at these junctions or changes in direction as leakage or even failure problems can occur if a joint is improperly made to account for an excessive angle developed by a poor alignment.

Thrust Blocks

The majority of pipes used for watermain work have joints which are not restrained longitudinally. The pressure in the watermain exerts a force on the pipe at bends, closed valves, tees and hydrants. Good thrust blocking practice is important to reduce breaks and leaks caused by these forces. Anchorage may be required in a vertical as well as a horizontal direction.

Thrust blocks are, therefore, installed on the outside of bends and tees to counteract these forces and can be formed of concrete, concrete blocks or wood placed in a manner that will transfer the forces to firm surrounding ground.

Thrust is only a problem at valves where there are couplings as the couplings cannot transfer the thrust longitudinally along the main. Generally, there is a valve chamber at these locations which is designed as a thrust block.

BEDDING

As discussed earlier, the route of a watermain is not necessarily a straight line and the conduit may be designed with a minimum cover. It is reasonable to expect that a contractor will use a minimum of trench sheathing material in his watermain construction except for larger pipes either with deep and wide trenches or located in a roadway. Under these conditions, excessively wide trenches or slash trenches might occur and cause problems with excessive loading on the pipe. A slash trench could have a slope of greater than 1 to 1. The trench bottom must first be drained, cleared of all stones and lumps and properly prepared to accept the bedding. The material under the pipe, generally

crushed limestone or even clear stone should be graded and compacted to the desired thickness. The bedding must support the pipe over its entire length. Special care must be taken at the joints to ensure that the pipe does not rest on the bells of the joints alone. After the pipe has been placed and jointed, the sides should be backfilled and properly compacted to prevent lateral movement of the pipe and then carefully backfilled with granular material to about 300 mm above the pipe before further backfilling proceeds.

MATERIALS USED IN WATERMAIN CONSTRUCTION

There is a good selection of pipe materials available for construction of watermains. Some are for specified applications, others are satisfactory for general use. The most common materials in use are:

1. Ductile Iron
2. Cast Iron
3. Reinforced Concrete
4. Steel
5. Asbestos Cement
6. Pressurized Plastic

Factors to be considered in the selection of the pipe are:

1. Cost
2. Availability in size and class
3. Ease of laying and jointing
4. Structural capacity in place
5. Facility for thrust restraint
6. Corrosion resistance
7. Bedding requirements
8. Types of joints

The most common joints used in pipe laying are:

1. Mechanical joints
2. Push-on joints
3. Field Welding
4. Victaulic couplings.

CONSTRUCTION CONSIDERATIONS

There are certain important points that the inspector should pay particular attention to during construction. Some of these are as follows:

1. The bedding must be to grade and a hole dug out for the bell to prevent bridging of the pipe from bell to bell on the bedding.
2. Final adjustments may be made to the pipe grade by placing pieces of wood under the bell or front edge of the spigot piece but these must be removed when the grade is set.
3. The trench width should not exceed that shown on the drawings.
4. The bedding must be compacted under, around and over the pipe.
5. Large boulders must not be included in the backfill.
6. Compaction methods must ensure that all voids caused by removal of sheathing are filled.
7. Thrust blocks must be taken to firm, undisturbed ground.
8. Valve nuts must be kept clear of backfill material, and placed in a vertical position.

SUBJECT:

CONSTRUCTION OF SEWERS, WATERMAINS, AND ASSOCIATED FACILITIES

TOPIC: 8

CONSTRUCTION SURVEYING

OBJECTIVES:

The trainee will be able to:

1. Prepare Grade Sheets for the layout of sewers.
2. Recall the role of the inspector during construction with respect to layout.
3. Recall some of the various methods of Construction layout.
4. Better understand basic surveying.

CONSTRUCTION SURVEYING

INTRODUCTION

General

Surveying has been described as the science and art of making the measurements necessary to determine the relative positions of points above, on, or beneath the surface of the earth, or to establish such points.

Thus, within this broad definition, all of the following fields are included:

Legal Surveying
Topographical Surveying
Mine Surveying
Hydrographic Surveying
Geodetic Surveying
Photogrammetric Surveying
Quantity Surveying
Construction Surveying

Although construction surveying was listed last, it is the most important to the inspector involved in the installation of municipal services such as sewers, watermains, and roads. He should be familiar with all related surveying theory, background, current construction practice such as Grade Rod Theory and Transfer of Grades, in addition to comprehending contract specifications and requirements, and some appreciation of the design considerations related to the facility being installed. The question is how much of this background understanding of design, specifications and surveying should the inspector be familiar?

It is difficult to give a precise answer. A general answer would be that an inspector should have enough knowledge of design and surveying so that he can properly perform his duties.

Usually, but not always, an inspector from a smaller municipality has a greater over-all knowledge of a project than his counterpart in a large municipality. It seems that the larger an organization grows, the more specialized become the various jobs. However, an inspector should not be so specialized that he has no knowledge of the problems involved in construction layout and grades.

The basic construction team for a municipality consists of the engineer, designer, surveyor and the inspector; often the inspector and the surveyor may be one and the same man. The inspector is the last link in the chain of personnel responsible for the correct construction of a project. He is often the last man capable of detecting an error - either in design or layout. Therefore, if he has a good over-all knowledge of his job, he will be able to spot discrepancies that may arise, and in doing so, avoid the waste of materials and money.

A good example of a possible source of error is in the level shot, when the instrument man makes an error in reading or recording a rod shot on a grade stake. It is impossible to check, but there is a good possibility that the error will show up on the grade sheet. A capable inspector may detect such an error by noting that the erroneous grade does not fit in with the grades adjacent to it. Most surveyors, in fact, try to establish their layout in such a way, that possible errors are more easily detected by themselves or by the inspector.

The division of responsibility for survey work varies depending on the job specifications. The survey work may be done in any one of the following methods:

1. The Contractor undertakes all the layout.
2. Either the Contractor or the Surveyor carries out the layout, and the other party checks it.
3. The Surveyor provides the layout.
4. The Inspector does the layout.

Under alternative (2) it would not be necessary for both parties to conduct the complete survey, but rather certain check points would be selected such as Bench Marks and manhole stakes, and these would be 'shot' with an instrument. Comments which will be made later concerning 'checking' may be taken to apply to the Inspector checking the Contractor's layout or to the Inspector checking his Surveyor's layout.

Under no circumstances should the contractor's instrument man and the inspector work on the same survey team. All checks should be done independently.

CONSTRUCTION SURVEYS

Background

The Contract Drawings will provide sufficient information to properly layout all the indicated services both in terms of Horizontal Orientation and in Vertical Relationship to the surface of the ground.

Horizontal control is provided by means of:

1. A legal survey plan, showing dimensions and bearings of property boundaries in a subdivision.

2. A centre line alignment drawing, giving tangent lengths and azimuths as well as appropriate circular and spiral curve data sufficient to lay out services.

3. A co-ordinate grid system, having key control points identified by co-ordinates, which are then used to locate other construction points.

Vertical control is usually provided by bench marks related to the basic network of high accuracy bench marks established by the Federal Government.

The Contract Drawings will always show a "Site Bench Mark" which will be related to either Geodetic Survey Datum or Hydrographic Survey Datum. This may, in fact, be some distance from the sewer to be installed and the Inspector will then have to transfer his bench mark to within 60 m of the start of the sewer and thence establish temporary bench marks (T.B.M.) at each street intersection, or at approximately 150 m intervals to the end of the job. This system of T.B.M.'s would then be looped back on the original bench mark. After all of the T.B.M. levels have been reduced and checked they may be made available to outside parties.

During the detailed design, the designer selects the sewer locations and elevations with the following points in mind:

1. The ground over which the sewer passes must be within the jurisdiction of the sewer owner, either under direct ownership or by means of easements or lease agreements.

2. There must be no conflict with existing buildings or underground pipes.

3. The gravity sewer must be high enough to drain into the top end of the existing system.

4. The sewer should be low enough to drain all house basements.

5. The slope of the sewer must be sufficient to provide a flow velocity of at least 0.6 m/sec with the sewer flowing full.

Preparation For Surveying

Prior to any surveying being carried out, the surveyor should be fully briefed by the resident engineer or inspector as to the specific stakeout task, the acceptable tolerances, the expected time to completion, and any other information that would affect the stakeout work. This is an important point, as a misunderstanding of the work to be carried out can lead to a loss of time by the field party, a loss of production by the contractor and a general lack of confidence and co-operation among all concerned.

The stakeout of the various services to be constructed, together with the contractor's ability to follow accurately the field lines and grades, determine the ultimate conformity of the completed works with the design specifications and drawings. Obviously any errors on the part of the field personnel, if not detected will have serious repercussions.

It is therefore essential that all stakeout work be independently checked for line and grade before grade sheets are completed and handed to the contractor.

Before commencing a stakeout, the surveyor should have in his possession the following:

1. Field job file, containing a complete set of "Approved for Construction" drawings for the project under construction, list

of local bench marks, copy of an *up-to-date* registered plan, and any previous relevant field notes.

2. A complete set of equipment in good adjustment, including notekeeping equipment.

3. Written instructions, when possible, outlining specifically the work to be carried out.

The first thing to do upon arriving at the work site is to obtain an overall view of the project, with the intention of determining the most efficient way of completing the job, i.e. accurately in the shortest time. Study the plan for a few minutes in relation to the surrounding area, noting any unusual features such as services not in normal location, flow directions, physical obstructions to layout, and so on. It has been proven many times that a little time and thought spent at the beginning of a stakeout, can save hours of time lost, when work had to be re-done because of the lack of planning or a full understanding of the task.

Construction Layout

Once the Surveyor has familiarized himself with the work, he can then proceed with the layout of the sewer, or whatever, by determining the location of the manholes from the contract drawings in relation to known points such as iron bars.

If there are several manholes in a straight line it may be advantageous to stake the first and last manhole in line. Using a right angle hand prism, or for greater accuracy a transit, two offset stakes are established on the side of the sewer line opposite to that on which the backhoe will cast the excavated material. For shallow sewers the offset would be 4 or 5 m increasing to 7 or 8 m for large, deep sewers.

Stakes are usually 50 mm x 25 mm x 450 mm rough lumber pointed at one end. They must be driven down accurately as the exact offset line is marked on the top of the stake, with a 25 mm nail driven part way into the stake to indicate the offset line. Stakes must be marked with the proper chainage, offset distance, direction, and preferably the nature of stakeout (i.e. san or storm) to avoid confusion by contractor's crews.

Intermediate stakes are then driven in at 10 m intervals starting with Sta. 0+00 at the M.H. and finishing with the next M.H. A nail is located on line at the top of each stake (see Figure 8-1).

When laying out a sewer the surveyor can start his chainage (stationing) at the low end of the work and then continue it through several manholes to the upper limit of the job. However, the surveyor usually begins a new chainage at each new manhole. In this case each new manhole, or existing one (if the project begins at an exisitng manhole), has an initial chainage of 0+00.

As soon as the stakes have been laid out the Contractor must be informed and instructed to protect them by means of larger stakes or boulders so that they are not disturbed by trucks, bulldozers or children.

In all cases when extending or connecting into an existing line, the offset at the appropriate end must be taken from the existing service, and not from plans. e.g., when extending an existing line the offset must be taken from the sewer line and not from the manhole cover.

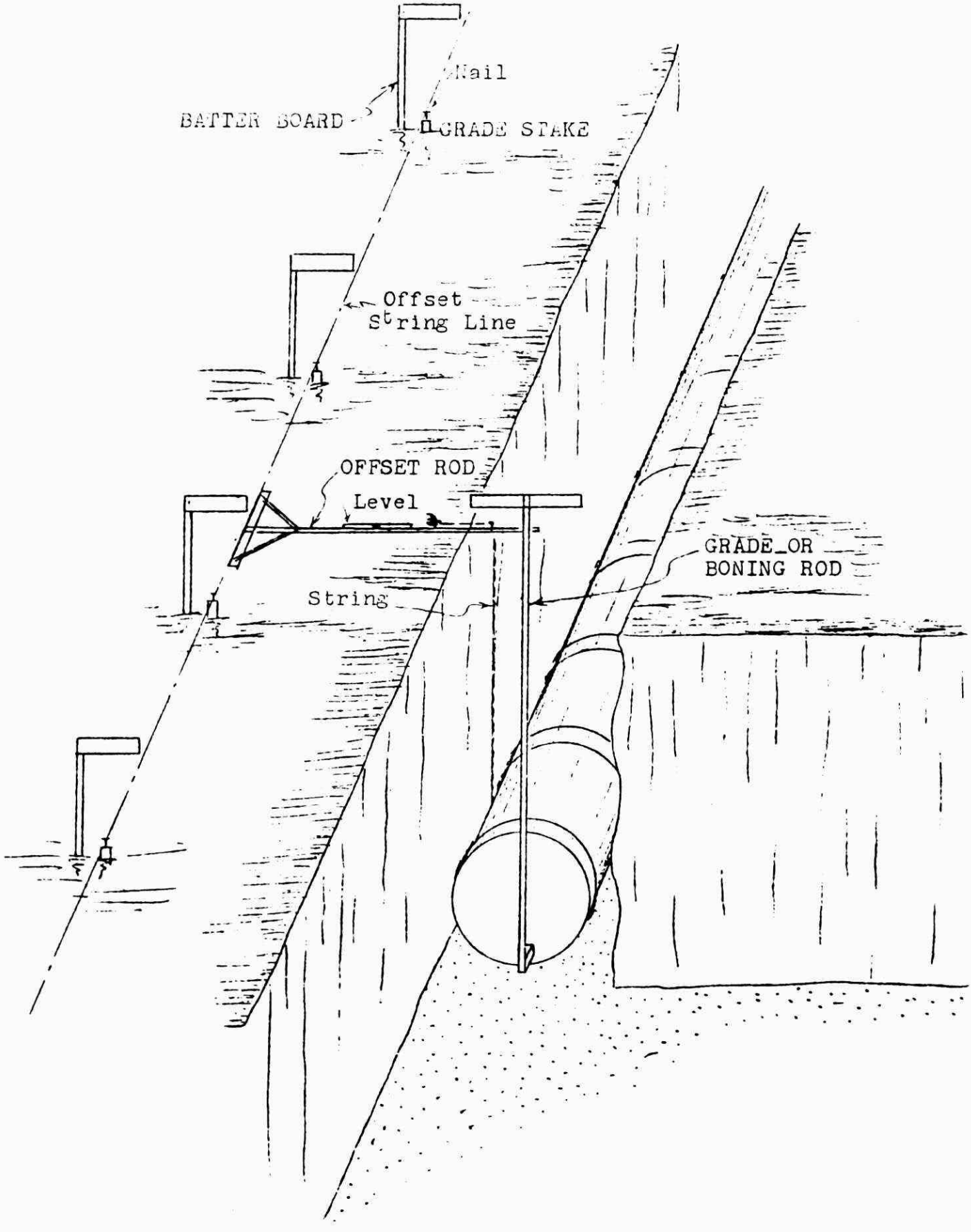

Nail
BATTER BOARD
GRADE STAKE
Offset
String Line
OFFSET ROD
Level
GRADE OR
BONING ROD
String

Figure 8-1

At the time of stakeout, the Contractor should expose the end of an existing service in order that the surveyor can confirm the elevation and location of the existing invert.

On standard subdivision roads sanitary and storm sewers usually run parallel and 3m apart being respectively 1.5m from centreline. Where both manholes are on a straight portion of the road, the manhole at the low end of the line should be located first, and offset at right angles to the centreline.

Where starting a line at a street intersection, or at any location at which the '0+00' stake cannot be set or may be disturbed, a '0-5' stake should be placed to provide the contractor with a sight beyond the end point. The distance to the minus stake may of course be varied to suit local conditions.

Distances from manhole to manhole are given on the construction drawings and usually represent scaled distances. It is advisable to check the given distances with a scale before accepting them, or, to compare the individual distances added together on a given street with the total chainage of the same, making allowances for intersections. If no errors in distances are apparent, the distances should be kept as shown on the drawing. The terminal manhole is to be located prior to stakeout of the offset line and the actual chainage determined by measurement on a straight road between intersections. The distances are calculated and any discrepancy in the last length can only be due to inaccurate chaining, but on a curved road with scaled distances, a discrepancy of a metre or so can be accepted as normal.

Locating manholes at irregular intersections or on curved portions of a road is easiest done by scaling the

distances from the two or three nearest survey bars and intersecting the arcs of respective scaled values. The intersection angle should be as close to a right angle as the situation permits. Having located MH.A this way, MH.B, can be located also by scaling the distance of centre-line of the sewer from the nearest B.C. or E.C., and projecting it by the scaled distance to MH.B. Having done this, we can offset from both manholes and establish the offset line. The actual distance measured should agree reasonably well with the distance given on the drawing.

Situations are common where the party chief cannot follow any fixed procedure in laying out sewer lines and must depend on his own best judgement in choosing the method that guarantees the closest possible adherence to the design. Often it is necessary to re-establish the road allowance and the nature of available evidence suggests the method for doing this. Special care should be taken when a manhole on a curved portion of road is located near the curb.

As the stakeout progresses, final tie measurements should be made from the proposed manhole locations to any adjacent survey bars, existing manholes, etc., to ensure that no blunders have been made. These should be made on tracing paper of field note size as shown in the sample field notes, so that the inspector can check the stakeout in the office.

On every lay-out job checking one's own work is never a wasted effort though in 99 times out of 100 it may appear so. There is an infinite variety of possibilities for errors and the best policy for the party chief is to establish a routine whereby no essential step in his lay-out work is left unchecked. Not only the actual measurements deserve attention, but also the basic information from

which he started out deserves a second scrutiny. Superficial digestion of information given on drawings may result in serious errors. It is brought to the reader's attention that the Laser Beam is currently being used for construction layout purposes, however a full discussion on its use is included in Appendix 8E.

Construction Grades

Levels to establish grades for the various services are taken on the grade stakes. New rodmen should be strongly reminded to take elevations on the top of the stakes, not on the ground. Levels are normally taken to the nearest 5 mm and must be originated on one bench mark and terminated on another. Elevations of existing services, to which services under construction are to be tied, must be taken, even if the existing services were only recently installed.

If there is any doubt as to the elevation of a bench mark, i.e. vague source, signs of physical damage, etc., a check must be taken. All bench marks must be used as turning points.

When establishing bench marks, select only points which will remain undisturbed throughout the construction period, and don't hesitate to set more than you feel will be adequate. Bench marks must always be carefully described. i.e. "B.M. 5B" is not adequate. The notes taken during the setting of B.M. 5B may be lost, and then so is the bench mark.

All turning points and points sighted must be properly and adequately described. Stake stations must be carefully noted at the time of stakeout, i.e. don't level the grade stakes, then complete the notes in the car or office.

Field notes must be checked for closure, i.e. add back sights and foresights, before leaving the field.

GRADE SHEETS

General

A grade sheet is the tabulated form of providing to a contractor all the information pertinent to the installation of a particular facility. The grade sheet should enable the contractor to install the particular sewer, or whatever, as indicated on the contract drawings. Grade sheets are necessary for the installation of a variety of different services including:

1. storm and sanitary sewers
2. lateral service connections
3. water mains
4. water services
5. curbs (but usually, not sidewalks)
6. catchbasins
7. road grading and sub-grade.

The information contained on a sewer grade sheet includes:

1. Project name
2. Date
3. Contractor's name
4. Type of sewer - sanitary or storm
5. Location of the sewer line, as well as the upstream and downstream manhole numbers
6. Sewer size, type, grade, bedding and backfill
7. Location of the lateral connections - chainage and direction

8. Manhole number, type, depth and relationship of the inverts w.r.t. the lowest invert
9. Signature of the person who computed that grade sheet
10. Layout stations, stake elevations, invert elevations, cut depth and measurements to the batterboard.

Grade sheets are generally made out by the inspector, but if this is not possible, they should be computed by the surveyor who carried out the stakeout. However, here are some general observations to bear in mind.

1. The grade sheet must be accurate as an error may mean a very expensive mistake in construction.
2. Completing the grade sheet is the time when the inspector will probably look at the drawings in the greatest detail, so he should take this opportunity to check if there are any inconsistencies or mistakes on the drawings which may require clarification by either the design engineer or the supervision engineer.
3. The inspector must realize that the construction foreman who receives the grade sheet may not have seen the drawings, so a note or diagram should be on the grade sheet, drawing the foreman's attention to anything unusual such as a drop connection or a special type of manhole cover.

Cut Determination

Usually the slope of the sewer is given but sometimes it must be calculated. From this slope, the sewer invert elevation at each of the grade stakes is found. Occasionally, the top of the pipe is the reference point rather than the pipe invert. The reference point must be clearly indicated and described. Normally, slope is given as a per cent.

$$\text{i.e. \% Slope} = \frac{\text{Difference in elevation}}{\text{Horizontal Distance}} \times 100$$

$$\text{Therefore a 2.5\% slope} = \frac{2.5 \text{ m}}{100 \text{ m}} \times 100$$

i.e. the slope is 0.025 m per linear metre

To calculate the invert elevation at chainage "X", take the invert elevation at Sta. 0 + 00 and add to it the slope times the distance to chainage "X". This is taken to two decimal places. An electronic calculator can be used to considerable advantage in these calculations.

At this point it is wise to remember that all calculations should be checked. If you are subtracting B from A to get C then add B and C to see if you arrive at A again. By the same token, invert elevations can be derived by a process of repeated additions.

When the elevation of the top of the offset stake has been determined, and when the elevation of the proposed sewer or structure is known opposite that station, then we can calculate how much we must measure up or down from the top of the stake to be at the proposed elevation of the structure at that point.

Example: We know that the elevation of a proposed sewer invert at a particular point is to be 125.00. The surveyor determines the top of stake elevation to be 127.44. We now know that if we measure 2.44m down from the top of the stake that we will be at the proposed elevation. We call this a cut of 2.44m (if the stake had been below the proposed elevation, we would have to measure up, and in that case we would be talking of a fill of x metres. These cuts and/or fills are entered on the grade sheet which is then given to the Contractor.

Grade Transfer

The next point to consider is how to transfer the cut, or fill, dimension from the top of the stake across the offset distance to the proposed construction. This can be done directly where the offset is small by using a carpenter's level and a straight edge; however, where the offset is more than 1.5m the transfer is done by means of "batter boards", (see Figure 8-1).

Most text books suggest that batter boards be placed across the trench with nails driven in the top to hold the centre line for the pipe. However, with the advent of extremely efficient excavating machinery, that method has become obsolete. Batter Boards are now located adjacent to the grade stakes on the opposite side of the trench to the excavated material.

A batter board is a 50mm x 100mm post placed firmly in a vertical position near the grade stake. A cross-tee is nailed to the batter board at a specified distance 'H' above the top of the grade stake. The distance 'H' is different at each grade stake and is calculated so that all the cross-tees are parallel to and some even number of metres above sewer invert.

For example, if the top of the grade stake represented a cut of 480mm, the Contractor would make H equal 250mm, 450mm, 750mm, etc. depending on what grade line fitted best with the other grade stakes. If the Contractor made H equal 250mm he would have a reference grade line 730mm above his proposed grade line - if he made H equal 450mm, the reference line would be 930mm above his proposed grade line. The important thing to note here is that although the H dimension would be different for each stake, the cross-tees would all be the same distance above the proposed sewer grade at each stake.

Once he has all his cross-tees set properly, the Contractor can sight down from the tees and check levels at any point along the sewer line.

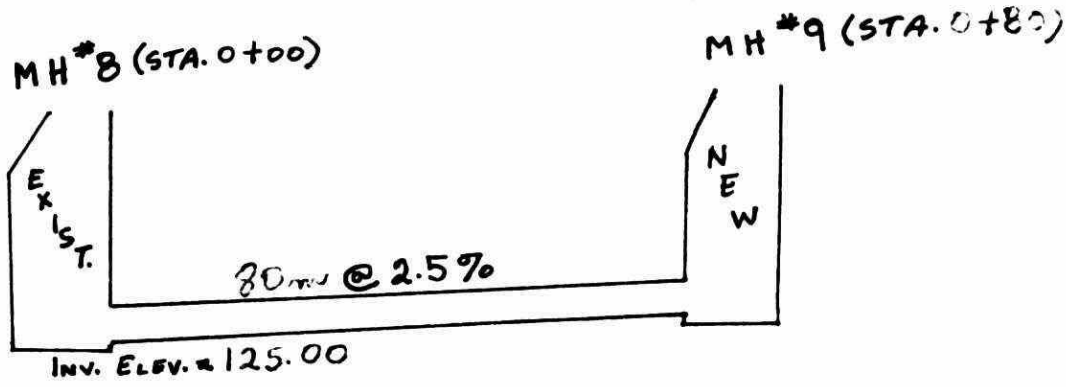
In the case of a fill grade, say 480mm, the Contractor knows if he measures up the batter board stake 480mm that he will be at proposed grade, however, this would leave him little room in which to work so it is usually found that the Contractor will utilize a vertical offset of at least one metre. In this case, he would actually measure up the large batter board a minimum of 520mm and so have a constant cut measurement of at least one metre from his level line of sight on the cross-tee.

A grade rod, or boning rod, is a measuring pole constructed so the distance from a cross piece at the top to the bottom of the pole is the same as the distance between the set batter boards and the proposed grade. If the Inspector sights over the batter boards and finds that the cross arm of the grade rod lines up exactly with the plane of the tops of the batter boards, he knows that the boning rod is on grade. If it doesn't line up, the necessary adjustment up or down is made in the trench. A minimum of 3 batter boards is necessary for any one accurate sighting. Sometimes additional cross pieces can be fixed to the boning rod to indicate trench bottom or a second pipe.

The length of the boning rod and the height of the batter boards is determined by the depth of cut. The plane of the top of the batter boards must not be so low that the Inspector has to lie on his stomach to sight them, or so high that the line across the boards is over his head.

Example:

It is proposed to extend an existing sanitary sewer 80 m. We know that the invert elevation of the existing manhole (M.H. #8) where we will make the connection is 125.00. Also based on the various design parameters, the sewer must be installed at a grade (slope) of 2.5%.



Let us now prepare the Grade Sheet for laying this sewer out.

1. It is necessary to set out an offset line with grade stakes at 10 m intervals along it. Use the existing M.H. #8 as Sta. 0+00. This makes the new M.H. (#9) Sta. 0+80.

2. By measurement, we find that the elevation of the top of each of the grade stakes along the offset line is as given in the column "Stake Elevation" on the Grade Sheet (Figure 8-2).

3. Determine by calculation the invert elevation of the sewer opposite each of the grade stakes (Sta. 0+00, 0+10, 0+20, etc.). This is done by using the formula given on Page 8-14. i.e. Invert Elevation at Sta. X = Invert Elevation @ Sta. 0+00 + Slope times the distance X.

Example

$$\text{IE Sta. } 0+30 = \text{IE (Sta. } 0+00) + \frac{2.5}{100} \times 30$$

$$= 125.00 + 0.75 = 125.75$$

OR

$$\text{IE Sta. } 0+10 = 125 + \frac{2.5}{100} \times 10 = 125.25$$

Using the above formula, the Elevations given under the column "Invert Elevation" on the Grade Sheet (Figure 8-2) were found.

4. By calculation we determine the difference in elevation between the sewer invert and the top of the grade stake at each of the Stations. This is the information given in the column "Cut" on the Grade Sheet.

5. By trial and error determine the most suitable grade rod length. If we try 3m at Station 0 + 08, the top of the batter board will only be 525mm above the stake - this is too low. If we pick a grade rod of 5m we would be 2.575m above the stakes with the batter boards - this is too high.

Rule of Thumb: The grade rod is obtained by taking the greatest figure in the "cut" column and adding 1 metre to the next highest metre, i.e. if the greatest figure in the "cut" column is 2.475m; the length of the rod could be 4m.

Use grade rod length of 4m for this example.

6. To determine how high above the top of the grade stakes we must measure to have a line of batter boards parallel to and 4m (the length of the grade rod) above the sewer invert, subtract the "Cut" from the grade rod length. This information is given in the left side of the column "stake to Batter Board". The right side is the conversion to millimetres so the contractor can easily set up his line of batter boards.

GRADE SHEET

CONTRACT NO. .....

CONTRACTOR.....

Layout by..... Book No. ..... B.M. .....

Gradient..... ..... 2.5%..... Offset..... Grade Rod ....4m.....

Station		Stake Elevation	Invert Elevation	Cut	Stake to batter board	
					m	mm
Backsite	0-10	127.410	124.750	2.660	1.340	1340
M.H.8	0+00	127.460	125.000	2.460	1.540	1540
	0+10	127.650	125.250	2.400	1.600	1600
	0+20	127.585	125.500	2.085	1.915	1915
	0+30	127.960	125.750	2.210	1.790	1790
	0+40	128.105	126.000	2.105	1.895	1895
	0+50	128.180	126.250	1.930	2.070	2070
	0+60	128.355	126.500	1.855	2.145	2145
	0+70	128.540	126.750	1.790	2.210	2210
M.H.9	0+80	129.475	127.000	2.475	1.525	1525

BEDDING:- TYPE B

LOCATION OF TEES:-

RIGHT	0+25	0+40	
LEFT	0+10	0+30	0+70

FIGURE 8-2

Alternative Methods of Grade Transfer

As an alternative to batter boards but less accurate and not recommended for general use are the Carpenter's level, String level and Hand level. All these contain a liquid with an air bubble in a curved tube which centres itself in the tube when the instrument is level.

1. Carpenter's Level

This level is mounted on a piece of wood or metal between 150 and 900mm long. The Carpenter's level can be placed on top of a straight edged piece of lumber to transfer grades up to 4m with an accuracy of 3mm.

2. String Level

This level is supplied with a hook at each end so that it can be hung on a string which is then stretched from the point of known elevation such as the grade stake to the centre of the work area where the elevation is required. The string level should be at the centre of the string so as not to be upset by the curve or catenary of the suspended string. The accuracy is 16mm in 1m.

3. Hand Level

This is a simple hand held tube with a 45^{o} mirror trained on the bubble and located in the line of sight. The tube is open at each end and there is a hair line to indicate the axis of the tube. The tube is rotated

vertically until the bubble comes into view and is bisected by the line of sight at which time the line of sight is horizontal. An observation may then be made of points of equal elevation, since no magnification is provided the viewing area is limited to about 15m. This method is the least accurate of any of those mentioned being only about 20mm in 1m.

House Connections

Tee connections for house service laterals should be located by stakes along the offset line. It is common practice to use the main elevation stakes for this purpose so that instead of an even 10 or 20m interval between stakes, the interval will vary to suit the house services. This means more work when calculating the grade sheet but less work on field layout.

In new subdivisions there will be little disagreement on the position of the house service. The builder will provide a plot plan and will ask for specific service locations for each different type of house in the subdivision.

In built-up areas the policy of each municipality will vary. It is customary to consult with each householder to find out where they would like the service brought in. This discussion can be abbreviated if a wooden stake is left with each householder, and he is asked to drive the stake at the point on the street line where the service is to terminate. The main sewer tee is then located opposite this point on the main sewer.

In extreme cases, and in order to avoid misunderstanding, the Municipality may draw up a " House Service Location Sheet" showing the service location as requested by the home owner. It is signed by the owner and copies distributed to the interested parties including the Inspector and the Contractor. This procedure is foolproof but rather time consuming.

Checking of Layout

The layout is now complete, but the first sod hasn't yet been turned, and the Inspector's job is only just beginning. Remember that the Inspector is the last vital link in the design-supervision chain.

You will notice that the first stake on the grade sheet is at chainage 0 - 10. This stake and batter board may be erected where the manhole is being excavated. Before any pipe is laid the next two batter boards must be erected and all three checked to see that they are in line. *A minimum of three batter boards must be in position at all times.* In this way most errors in layout, levelling or calculation may be detected immediately. An error in selecting the sewer slope will not show up in this way.

The boning rod should then be made up with the toe well braced in position at right angles to the shaft, and the cross-tee firmly nailed in position at right angles to the shaft in the other direction. *Measure the distance from toe to cross-tee to see that it agrees with the grade sheet.*

Now proceed to the batter boards and check the dimension "stake to batter board" against the grade sheet and set a hand level on top of the batter board to see that it is truly level, if it is off, correct it and check the distance down to the stake.

Since the batter board does not span the trench a small variation from level will throw your line of sight off considerably.

Place the boning rod vertically with toe in pipe invert. Always sight in the same direction, preferably in the direction of pipe laying. The boning rod tee must be in exactly the same plane as the three batter board tees.

The Contractor must set a string line between the first and third grade stakes, it will be fixed to the nail on top of the two stakes mentioned and should pass right beside the nail in the intermediate stake. *The string line should be on a minimum of three stakes at all times.*

The Contractor should then make up an offset rod with a small right angle tee at one end. Two nails are placed along the rod at the correct offset distance from the tee and a plumb bob and string hung down. On small pipe the plumb bob will be situated at pipe centre line, on 600mm diameter pipe and larger the offset measurement on the rod is often reduced by half the pipe O.D. so that the plumb bob marks the outside edge of the pipe barrel. In either case, the Inspector must check the offset rod length from tee to plumb bob nail and also see that the tee is held gently against the string line without moving the string.

Finally, the Inspector enters the trench and checks to see that the pipe lines up with the plumb bob.

QUANTITY CALCULATIONS

During the construction of a project, it is often necessary to calculate volumes of materials - the excavation of roadways, the excavation of sewer trenches, the amount of material removed from a borrow pit and so on.

Although there are a number of ways of computing volumes, one of the most common methods used which is simple yet accurate is the Average End Area Method. There are available a number of sophisticated computer programs which are based on this method and which can provide a wide variety of output data. We will at this time, only attempt to describe the approach to calculating quantities and direct the student to other, more advanced references, if he is interested in pursuing the computer approach.

The quantity calculation procedure by the average end area method is summarized as follows:

1. Take, original cross-sections of the area to excavated at suitable intervals.
2. After excavation, take the final cross-sections at the same locations as the original ones.
3. Plot both cross sections to scale and compute the difference in end area at each station by the Datum Line Method.
4. Having obtained the end areas at each section, set up the "summary quantity sheet" according to chainages as shown. The calculations using the mean distance between chainages and the end areas calculated earlier, will give the total volume excavated.

As can be seen, this principle can be readily adapted to compute sewer trench excavations, as the cross-section would be considerably simplified.

ILLUSTRATION OF THE THEORY OF VOLUMES
From
AVERAGE END AREAS

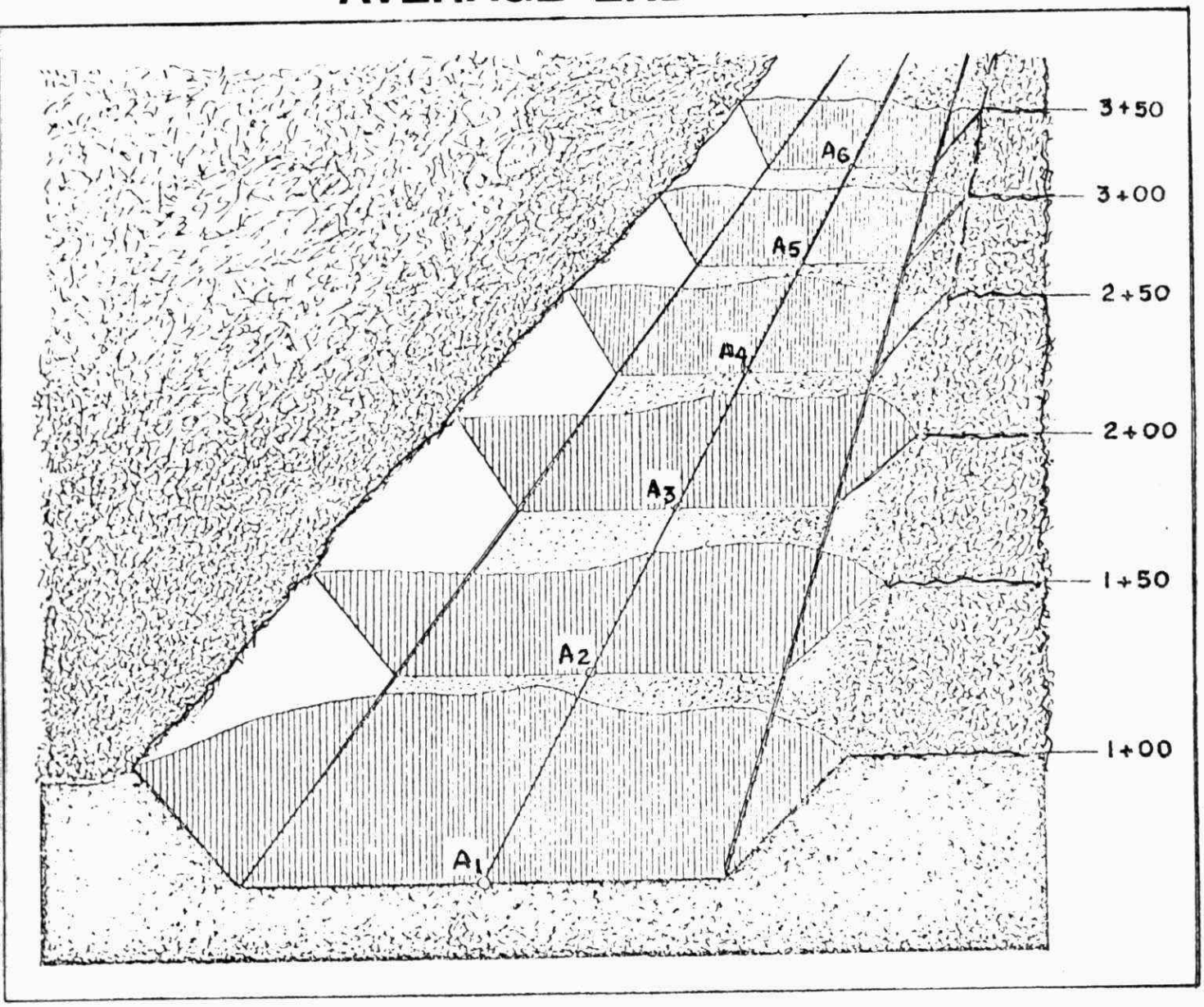


Figure 8-3

END AREA COMPUTATION BY DATUM LINE METHOD

1. Plot the cross sections (including the originals and finals) showing the elevations and offsets to the Department Standard.

2. Choose the next tenth datum line below the lowest point on the section. Any datum below the lowest point could be used but for ease in calculation the even ten is commonly used.

3. Average the depths to the datum line for each pair of points in succession on the original ground line

4. Multiply the average obtained between each pair of points by the distance between them.

5. Add the products obtained to get the area between the original ground line and the chosen datum line.

6. Repeat the same calculations using the final line and the same datum line. This will give the area between the final line and the datum line.

7. Subtract the final area from the original area to obtain the area of the cut section.

8. If fill section areas are required the same method may be used except that the original area be subtracted from the final area.

9. These calculations should be entered on Department of Highways form OB-C-3 and OB-C-4 as shown on the following pages.

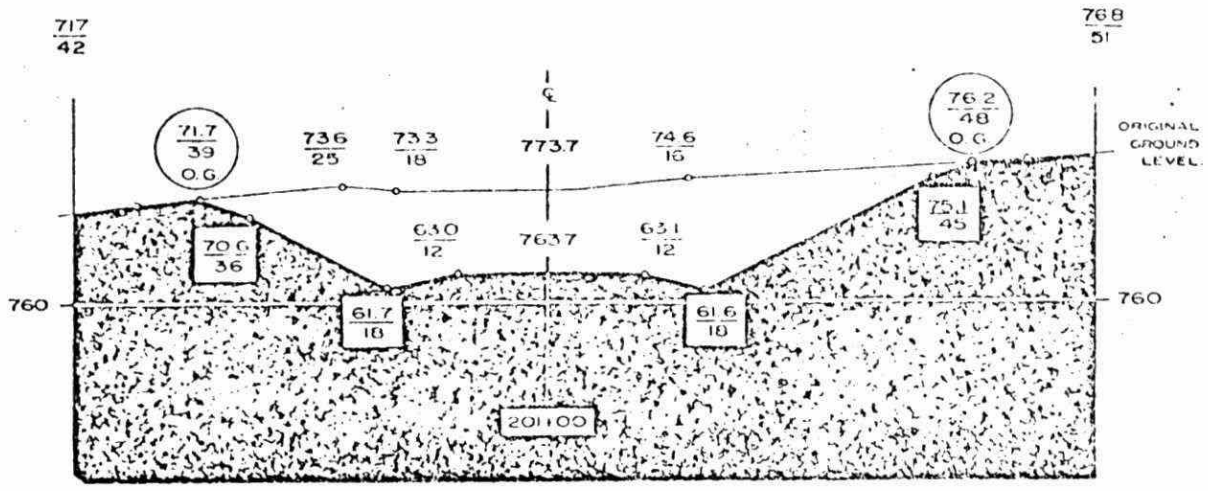


Figure 8-4

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS

ONTARIO

CROSS-SECTION SHEET

SHEET 9 OF 14 DATE August 8th 1973

CONTRACT NO. 65 + 122 ITEM NO 3 EARTH EXCAVATION

LOCATION OF MATERIAL ETC In Road Cut From Station 200 + to 203 + 80

STATION	PLUS	SUB-AREA	MINUS	SUB-AREA	END AREA
201+00	$\frac{(11.7+13.6)}{2}\times 14$	177.10			
	$\frac{(13.6+13.3)}{2}\times 7$	94.15	$\frac{(11.7+10.6)}{2}\times 3$	33.45	
	$\frac{(13.3+13.7)}{2}\times 18$	243.00	$\frac{(10.6+1.7)}{2}\times 18$	110.70	
	$\frac{(13.7+14.6)}{2}\times 16$	226.40	$\frac{(1.7+3.0)}{2}\times 6$	14.10	
	$\frac{(14.6+16.2)}{2}\times 32$	492.80	$\frac{(3.0+3.7)}{2}\times 12$	40.20	
	$\overline{87}$				
		1233.45	$\frac{(3.7+3.1)}{2}\times 12$	40.80	
			$\frac{(3.1+1.6)}{2}\times 6$	14.10	
			$\frac{(1.6+15.1)}{2}\times 27$	225.45	
			$\frac{(15.1+16.2)}{2}\times 3$	46.95	
			$\overline{87}$		
				525.75	707 70
	(CHECK)				or 708
201+60	$\frac{(22.2+21.5)}{2}\times 8$	174.80	$\frac{(22.2+21.6)}{2}\times 4$	87.60	
	$\frac{(21.5+18.8)}{2}\times 14$	282.10	$\frac{(21.6+18.8)}{2}\times 8$	161.60	
	$\frac{(18.8+14.2)}{2}\times 14$	231.00	$\frac{(18.8+10.9)}{2}\times 12$	178.20	
	$\frac{(14.2+9.2)}{2}\times 28$	327.60	$\frac{(10.9+10.6)}{2}\times 28$	301.00	
	$\overline{64}$				
		1015.50	$\frac{(10.6+9.2)}{2}\times 12$	118.80	
			$\overline{64}$		
				847.20	168 30
	(CHECK)				or 168

DETAILED BY R Greene CHECKED BY C Elliott SUBMITTED BY Revised

NOTE:

1 — THE ITEM NUMBER IN HEADING SHOULD INCLUDE THE DESCRIPTION.

2 — THE ABOVE NOTED "CHECK" IS VERY IMPORTANT.

3 — SUB AREAS ROUNDED TO TWO DECIMAL PLACES END AREAS ROUNDED TO THE NEAREST SQ.M.

4 — USE THIS AS DECIMAL LINE.

5 — USE SIGNATURES AND NOT INITIALS.

Figure 8-5

SUMMARY QUANTITY SHEET

SHEET ___ OF ___ DATE _____

DISTRICT No. _____ HWY. No. _____

CONTRACT No. _____ JOB NAME _____

LOCATION OF MATERIAL ROAD CUT STA 200+70 TO 203+80 ITEM No. 3 EARTH EXCAVATION

STATION	DIMENSIONS	DISTANCE	DOUBLE DISTANCE	MEAN DISTANCE	END AREA	CUBIC METRES
		0				
200+70	Start of Cut VF		30	15	527	7 9 0 5
		30				
201+00			90	45	708	3 1 8 6 0
		60				
201+60			80	40	168	6 7 2 0
		20				
201+80			40	20	557	1 1 1 4 0
		20				
202+00			70	35	1625	5 6 8 7 5
		50				
202+50			100	50	1891	9 4 5 5 0
		50				
203+00			130	65	2417	1 5 7 1 0 5
		80				
203+80	Zero of Cut		80	40	0	
		0			Cu. M.	3 6 6 1 5 5
203+80						
200+70						
310				310		
	(CHECK)					

DETAILED BY K Larsen CHECKED BY R.F.Flint SUBMITTED BY J Lelliott

NOTE

- The Item No. in the Heading should Include the number and description.
- The above noted "CHECK" is very important.
- Make this the Decimal Line.
- All areas to be taken to the nearest Sq. M.
- Detail Full Cut in Cubic Feet and then reduce to nearest Cubic Metre
- Use Signatures. (DO NOT PRINT)

Figure 8-6

GENERAL SURVEYING

Introduction

Surveying is an ancient art which can be traced to the earliest times. The Egyptians probably had the first well organized system of land measurement including angles and distances and the Romans must have credit for a sound understanding of the principles of the level as shown by the great aqueducts.

"Surveying" is a broad term and includes at least the following divisions:

Property or legal Surveying
Topographic Surveying
Construction Surveying
Mine Surveying
Hydrographic Surveying
Geodetic Surveying
Photogrammetric Surveying
Quantity Surveying

All of these are discussed in general terms in the Encyclopedia Brittanica covering five full pages.

The "Construction Surveying" portion of the Encyclopedia's reference covers only one tenth of one page. However, this is the area of prime interest to the construction inspector and is mentioned only to show that we are dealing in a highly specialized, or very narrow field, depending on the point of view.

REQUIRED MEASUREMENTS:

Essentially and very simply all surveying is involved with only three forms of measurement:

1. Distance
2. Elevation
3. Angular Displacement

And, slightly oversimplified, a separate instrument is used for each as follows:

1. Distance - Chain or Tape
2. Elevation - Level
3. Angles - Transit

Each of these operations will be discussed, although in practice, frequently at least two and often three different measurements are being taken simultaneously.

SURVEYING EQUIPMENT

The list of today's surveying equipment includes transits, levels, tapes and chains, chaining pins, plumb-bobs, stakes, marking crayons and field books; all of which must be of interest to the construction inspector.

In addition, the inspector must be aware that today's survey equipment also includes such highly refined apparatus as Shoran, Loran, and the Electronic Position Indicator, all of which use radar; the laser beam which uses visible light; the geodimeter which is a light-signalling instrument; and the tellurometer which uses radio microwaves.

APPENDIX - 8B

CHAINING

The Chain

A "chain" is a strip of steel approximately 6 mm wide and 0.7 mm thick and usually 50 m in length.

A hundred years ago a chain was a series of links and was usually sixty-six feet in total length; the word "chain" has persisted, but fortunately we now work in 50 m lengths.

Chains may be graduated in tenths, hundredths, and thousandths of a metre over the entire length or only in the first and last metre, with intermediate metre marks.

A "tape" is usually of cloth, fiberglass or steel and is not as accurate as a chain when used for cumulative measurements, i.e. running totals.

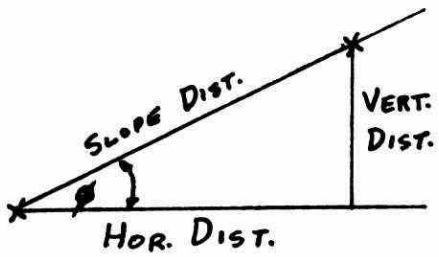
Corrections to Field Measurements

1. Chain Correction: A chain on tape must be compared with a standard to determine its actual length. For our purposes, a new chain is assumed to be exactly 50 m long. Older chains and repaired chains should periodically be checked, using a new chain as a standard.

2. Slope Correction: When a measurement is taken with the chain horizontal, there is no slope correction. Almost all measurements taken in municipal surveying are taken with the chain horizontal.

In the event that a measurement must be taken on a slope (i.e. not horizontal), the slope distance must be reduced to its horizontal equivalent. In order to do this, the angle of the slope with the horizontal must be taken. This angle can be taken with a transit or an Abney hand level.

Slope Distance = Distance Measured
Horizontal Distance = Distance Required
$\emptyset$ = Angle Measured



$$\text{COSINE } \emptyset = \frac{\text{HOR. DIST.}}{\text{SLOPE DIST.}}$$

Horizontal Distance = Slope Distance x Cosine $\emptyset$

As an example, a 50 m chain held with one end 1 m higher than the other will only give a horizontal measurement of 49.99 m, an error of 0.01 m, unless the slope correction is made.

3. Sag: If a chain is supported throughout its entire length (i.e. lying on the ground), a tension of 2.2N must be applied in order

that the chain give a correct measurement. If the chain is entirely un-supported (i.e. supported only at the ends), a tension between 4 and 5N must be exerted to give a correct measurement. The range between 4 and 5N is to cover the different weights of chains now manufactured. The most common imperial unit chain in municipal survey use is 100 ft. long and requires a tension of 24 lbs. when supported only at the ends. Chainmen should find out the correct pull for the chain they are using and get the feel of this pull so as to be able to exert this tension when chaining.

4. Temperature Corrections The coefficient of expansion of steel is 0.00000358 per degree Celsius. This amounts to about 0.002 m per 50 m per 10°C. A tape is standardized at 20°C.

Example:

If the temperature is 31°C., the chain would be longer by 0.02 m. If you wanted to measure out 50 m, under these circumstances you would measure out 49.998 m.

Good Chaining Practices

1. Find the exact points that mark the ends of the chain.

2. Find by what method the chain is graduated and note how it should be read.

3. Agree on a set of signals with the other members of the party such as calling chain, mark, O.K., etc.

4. Find by trial what the correct pull on the chain feels like.

5. Make sure of the foot reading by checking the numbers on either side of it.

6. The head chainman should keep approximately in line (if a transit is not in use) by looking backward over the line.

7. Do not jerk the chain or pull on it when it is kinked, since it will easily break.

8. The rear chainman should not get in the line of sight when the transitman is lining in the head chainman.

9. The rear chainman should not carry his end of the chain between stations; he should allow it to drag free.

10. Do not allow the chain to be humped by a high ground level between each end of the chain.

11. Tie the thongs close to the eye of the chain and leave the ends of the thongs loose.

12. Use chaining pins or call stations every 50m.

Accuracy

Even experienced chainmen have difficulty in preventing the chain and plumb-bobs from moving during measurement. The error from this source is between 1:5000 and 1:10,000 with a chain of average cross-section, 50 m long, supported only at the ends. Temperature may introduce an error up to 1:5000. If care were not exercised and if tension and temperature were thus ignored, the accuracy of the measurement would be in the neighbourhood of 1:2500. However, using care, proper tension and temperature correction, an accuracy of 1:5000 can be obtained.

Structural layout is taken to the nearest .005 m, pipeline layout and ties for "As Constructed" dimensions generally to the nearest 0.01 m.

APPENDIX - 8C

LEVELLING

The Level

The instrument used for accurate levelling is known simply as a "level" as distinct from a Carpenter's level, String level or Hand level.

A level consists of a telescope set on an adjustable horizontal plate which in turn is mounted on a detachable tripod so that the instrument is located at head height. The telescope has a bubble tube mounted on it and rotates about a vertical axis. The line of sight within the telescope is provided by cross hairs as described in Appendix 8D.

Adjusting the Level

The instrument is levelled by adjusting the screws which bear on the horizontal plate with further fine adjustment on the telescope tube itself. In order to ensure that the vertical axis is truly vertical, the level must be adjusted in two positions at right angles to each other. In order to check on the accuracy of the bubble tube, the telescope is then rotated 180° and if the bubble is off, it is brought back half way by levelling screws; the instrument is again rotated 90° and the same bubble error maintained by adjusting the levelling screws. Such a bubble tube error may be corrected by adjusting the capstan screws at one end of the bubble tube. However, since this is rather time consuming, most instrument men will simply allow for this error and live with it for several weeks before making the corrections. Level accuracy is not affected provided the error is known and the appropriate correction made to the level before taking a rod reading.

An error like the above is caused by the bubble tube not being at right angles to the vertical axis and is easily detected. If, however, the telescope line of sight is not at right angles to the vertical axis the error is not readily detected during routine levelling. In order to check for this error the instrument man must carry out the "Three Peg Test". This should be carried out at least once every six months and whenever a new instrument is used.

Three Peg Test

Three points, A,B, and C are set in a straight line such that AB = BC = 30m. The instrument is set up at B and elevation of A and C are shot and the difference in elevation obtained. The instrument is then moved close to A, (about 3m away), and A and C are again shot. The difference in elevation should be the same as before. If it is not, the telescope is focussed on C, the capstan screws holding the line of sight cross hair in the telescope are adjusted and the line of sight is moved until the correct reading is obtained at C. The reading on A is again checked and further adjustment is made where necessary until the difference in elevation between A and C is the same as it was when the instrument was set up at B.

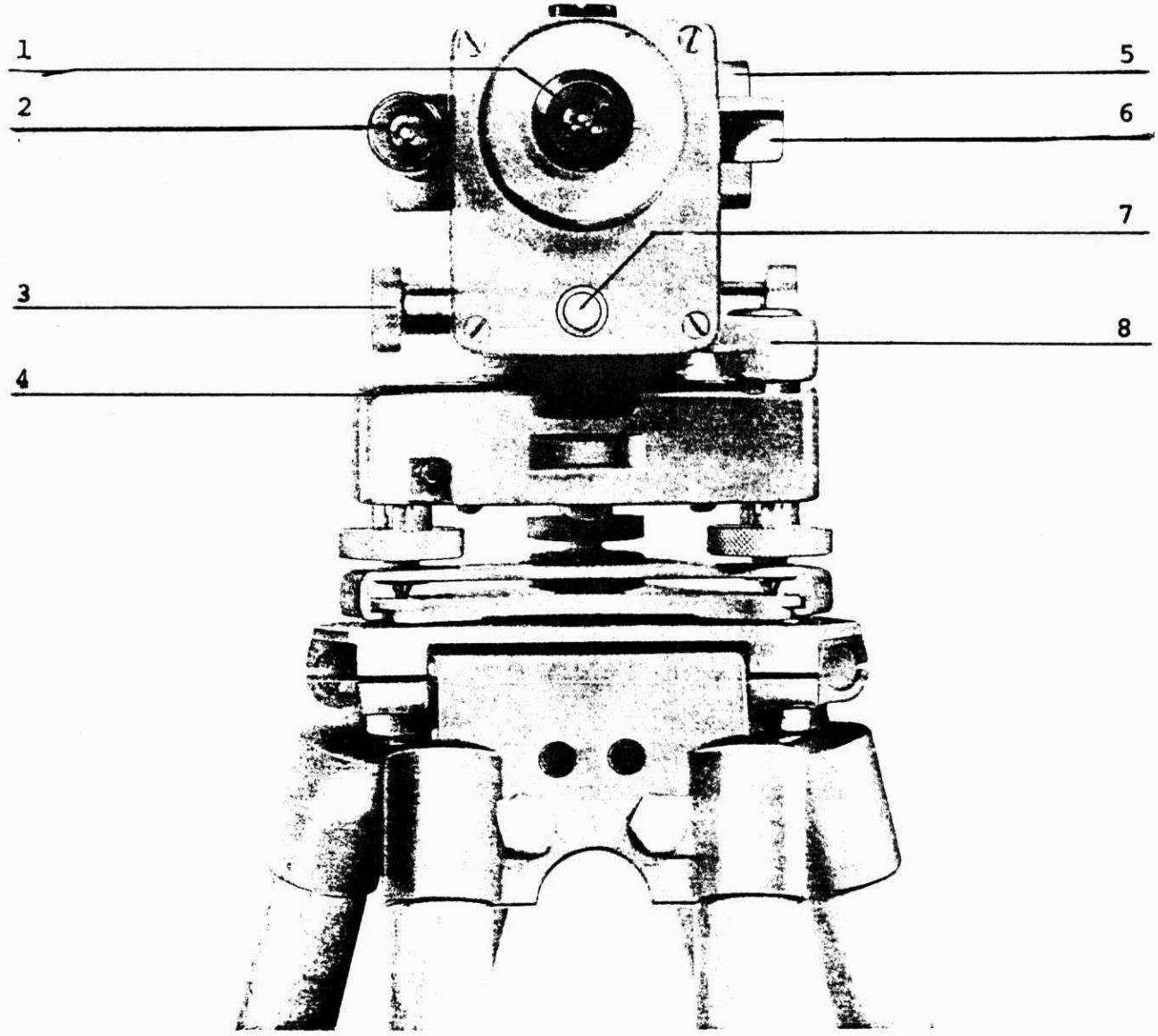
Theory of Levelling

1. Definitions: -

Levelling - is a method used for establishing elevations from a known elevation.

Elevation - Elevation of a point is its vertical distance above sea level.

Backsight - (B.S.) is a sight taken with a level to a point of known elevation.



Wild NAK2 Universal Automatic
Level, with horizontal circle

1. Eyepiece
2. Reading microscope for circle
3. Endless horizontal drive screw
4. Knurled rim for setting the circle
5. Focussing knob
6. Mirror for observing the circular bubble
7. Push button
8. Circular level

WILD AUTOMATIC LEVEL

Figure 8C-1

Intermediate Sight - (I.S.) is a sight taken on any point or object to establish its elevation.

Foresight - (F.S.) is a sight taken on a turning point to establish its elevation.

Turning Point - (T.P.) is a solid fixed point used temporarily to transfer an elevation, and thus provide continuity to a line of levels. When the level is moved to the next forward position, the T.P. becomes a point for the next backsight.

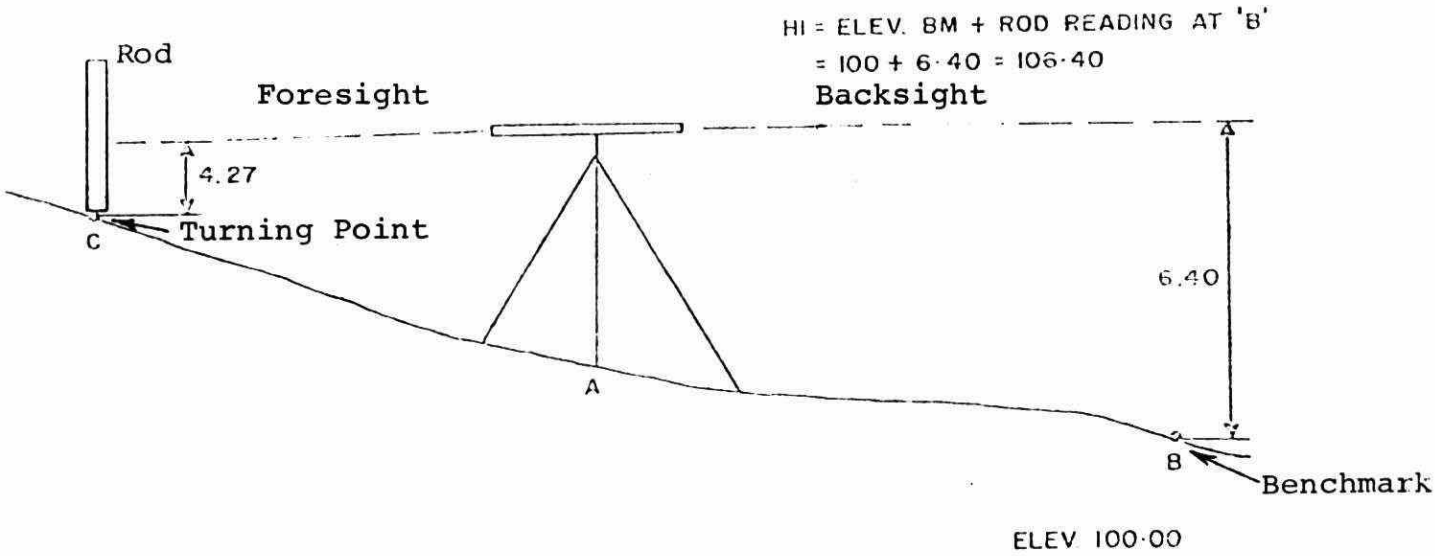
Benchmark - (B.M.) is a fixed solid reference point, the elevation of which is known. Benchmarks should be referred to the Datum or base of Mean Sea. Level at New York City which is taken as 0.000m. The Datum can be either Geodetic Datum, which takes no account of movement of the Earth's crust or Hydrographic Datum which does take account of such movement.

Height of Instrument - (H.I.) is the height of the level above a known elevation.

2. Example: -

Level is set at point A - elevation unknown
Rod is held on point B - known elevation 100.00
Rod reading as taken from point A is 6.40. Therefore, the line of sight is 6.40 above elevation 100.00, i.e. the height of instrument is 106.40. Now that the H.I. has been established, the elevation of a point C of unknown elevation can be determined by placing the rod on the point 'C' and subtracting the rod reading from the H.I., i.e. elevation of C = 106.40 - 4.27 = 102.13

ELEV 'C' = HI - ROD READING AT 'C'
= 105·40 - 4.27 = 102·13



SAMPLE FIELD NOTES
IF POINT A IS AT STA 1+25
AND POINT B IS AT STA 1+75
POINT C IS AT STA 0+75

(Elevation of B.M. is related to geodetic datum)

STA	B.S	HI	F S	ELEV	REMARKS
1+75	6.40	106.40		100.00	BENCH MARK
0+75			4.27	102.13	T. P

3. Suggestions for the Levelman:-

a) Choose a good solid place to set up the level where backsights and the foresights will be about equidistant from the instrument.

b) Avoid sights of more than 60m.

c) Any points of known elevation should be used as turning points as a check on the levelling accuracy to that point.

d) On steep slopes, resist the temptation to take unequal sights. Keep foresights and the back-sights equal.

e) Be sure that the level is set correctly before sighting; all four screws in a four-screw instrument should bear firmly and the bubble should be given time to settle before taking reading.

f) It is unnecessary to clamp the spindle and usually it is better not to do so.

g) Keep the bubble out of the direct sunlight - the heat will move it one way or the other, even though the instrument itself may still be level.

4. Suggestions for the Rod Man:-

a) Choose suitable turning points. Do not use objects that will settle or move. There should be a definite point for the rod to rest on, e.g. a local high point.

b) Mark all turning points and describe them to the levelman so that they may be easily found again.

c) In choosing a turning point, go as far from the level as the level is from the preceding turning point.

d) Keep the rod plumb, using either a rod level or by waving the rod. One or the other must be used when turning.

Accuracy

For Geodetic Surveying, the accuracy required (in metres)is

0.0032 x No. of kilometres.

For Third order of accuracy (normal levelling) the error in metres must not exceed 0.0095 x No. of kilometres.

i.e. If the distance levelled was four kilometres

the allowable error would be:

$$0.0095 \times 4 = 0.038\text{m}$$

$$= 38\text{mm}$$

APPENDIX - 8D

ANGULAR MEASUREMENT BY TRANSIT

General

The transit is one of the most complex instruments used in construction surveying. The accuracy it produces results from careful manufacture, good design, and the important fact that it can be so operated that it automatically eliminates any residual errors in its construction or its adjustment. The principle upon which this depends is the principle of reversal. It is introduced in the transit by mounting the telescope on the horizontal axis so that it will transit, and thus can be used, both in its normal position called direct and its inverted position called reversed, and by mounting the levels on a part that turns about the vertical axis.

Transits are designed for a number of specific purposes. The type described here is a repeating instrument equipped with a vertical circle and telescope level. This is called an "Engineer's Transit".

The transit consists of three main parts, the alidade at the top, the horizontal circle in the centre, and the levelling head at the base. The alidade includes the entire upper part of the instrument, i.e. the telescope, the standards, the verniers, the plate levels and the inner spindle (inner centre). The horizontal circle includes the outer spindle (repeating centre). The levelling head includes the levelling screws, the bearing for the outer spindle, and the threads that screw on the tripod. The alidade and the horizontal circle can turn independently in a horizontal plane about the vertical axis. The three parts are operated by two clamps, each equipped with a slow motion

screw. The upper clamp clamps the circle to the alidade and the lower clamp clamps the circle to the levelling head. When a clamp has been tightened, the appropriate slow motion screws can be used to make a fine setting.

For other details of Transit Construction reference should be made to more detailed publications on the subject such as "Plane and Geodetic Surveying" by D. Clark.

Measurement of a Horizontal Angle

By using the upper clamp and the slow motion screw, the zero of the vernier is set precisely opposite the zero on the graduated circle. Then by using the lower clamp and slow motion screw, the telescope is pointed at a target marking the other side of the angle to be measured. The circle remains stationary during this process while the vernier travels around the circle. When the sighting is complete, the position of the vernier gives the value of the angle.

The Telescope Sight

The telescopic sight consists of the following:

1. A pair of cross hairs mounted in a ring or reticle near the rear of the telescope tube.

2. Microscope, or eyepiece, which magnifies the cross hairs and must be focused on them according to the eyesight of the observer.

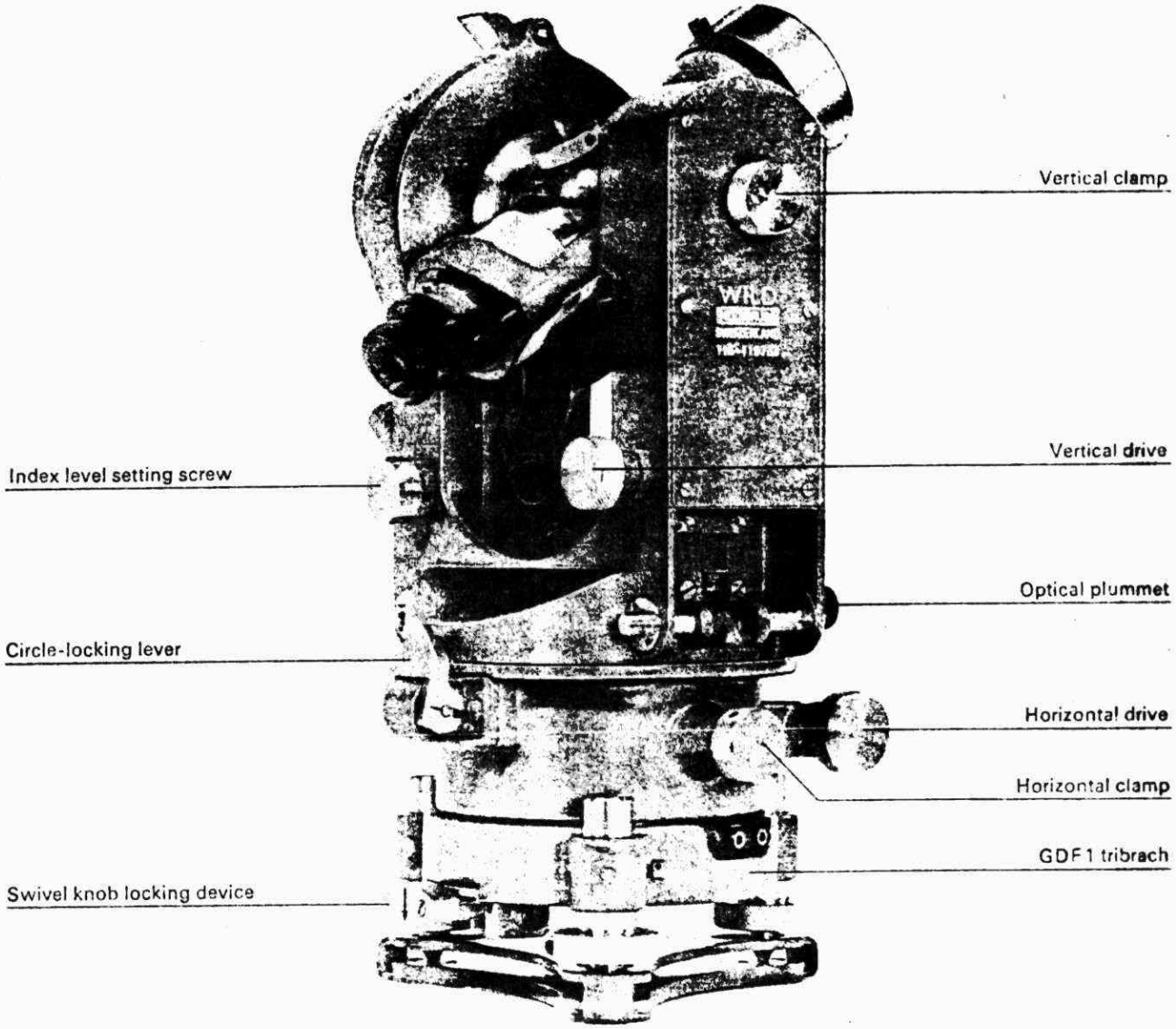
3. An object glass, or objective lens, which forms an image within the telescope.

The observer observes the cross hairs through the eyepiece and moves the lens backward and forward until the image is clear. This can occur only when the image is on the plane of the cross hairs. Under these conditions, the cross hairs become part of the image, and to the observer, they appear superimposed on the object toward which the telescope is pointed.

If the observer allows himself to look at the image instead of the cross hairs, it is possible to change the focus of the eye so that the image is seen clearly a short distance in front of or behind the cross hairs. The cross hairs will then appear blurred. When the image is not the same distance from the observer as the cross hairs, the cross hairs will move across the image when the eye is moved, just as is the case in observing two objects at different distances with the naked eye. Under these conditions PARALLAX exists and the direction of sight is not sure. When the telescope is properly focused, however, the cross hairs will always appear superimposed on the object, no matter how the eye is moved and therefore the telescopic sight will have a definite direction.

Verniers

A vernier, or vernier scale, is a short auxiliary scale placed along side the graduated scale of an instrument by means of which fractional parts of the least division of the main scale can be measured accurately. The accuracy of the vernier depends on the fact that the eye can more closely determine when two lines coincide than it can estimate the distance between two parallel lines. The graduated circle on most instruments is graduated in half degrees. When this is the case, the vernier is divided into thirty parts covering twenty-nine of the half degree divisions;



WILD ENGINEERS TRANSIT

Figure 8D-1

then readings can be accurately taken to the nearest minute. A single vernier is graduated only to the left of the index mark. A double vernier is graduated both left and right of the index mark. With such verniers, directions can be read clockwise or counterclockwise whenever desired. A clockwise angle is read from right to left and the set of divisions on the vernier to the right of the index mark is used.

Adjustment of the Transit

The inspector should not normally adjust the instrument, however, it is desirable to check the instrument for accuracy by double-centering when running a line, i.e. shooting the angle once with the telescope in the normal position and once after transiting by surveying the telescope 180° vertically and 180° horizontally. Also note any changes in the normal behaviour of the plate level bubbles which may indicate minor damage due to vibration or shock.

Care of the Instrument

1. Handle the instrument by the base when not on the tripod. This prevents deflecting the more delicate parts.

2. Never stand the tripod on a smooth surface. The legs may slip outward.

3. Always stand the tripod up carefully. The legs must be wide and firm even when the set-up is not to be used for observations. The wind or a slight touch may knock it over.

4. Never leave the instrument unattended unless precautions have been made for its protection.

5. Never subject the instrument to vibration. Vibration may put the instrument out of ad justment.

6. Never force the instrument. If the telescope or alidade do not turn easily, do not continue to use the instrument. Such usage might damage a bearing.

7. Keep the instrument in its case when it is not in use.

8. Place it in the case so that only the base is in contact with the case. Keep all three transit clamps tight. This reduces chances of vibration.

9. Keep the instruments free from dust and rapid changes in temperature. Dust ruins the finish and the bearings. Because of the nature of Municipal Surveying, it is inevitable that dust will collect on the instrument. When dust appears on the vernier scale, the instrument should be sent out for professional attention. Rapid temperature changes will introduce moisture into the telescope tube causing fog. Sometimes the telescope tube must be dismantled to remove this fog.

10. If the instrument is wet, let it dry by itself. Manual drying ruins the finish and smears the glass and graduations.

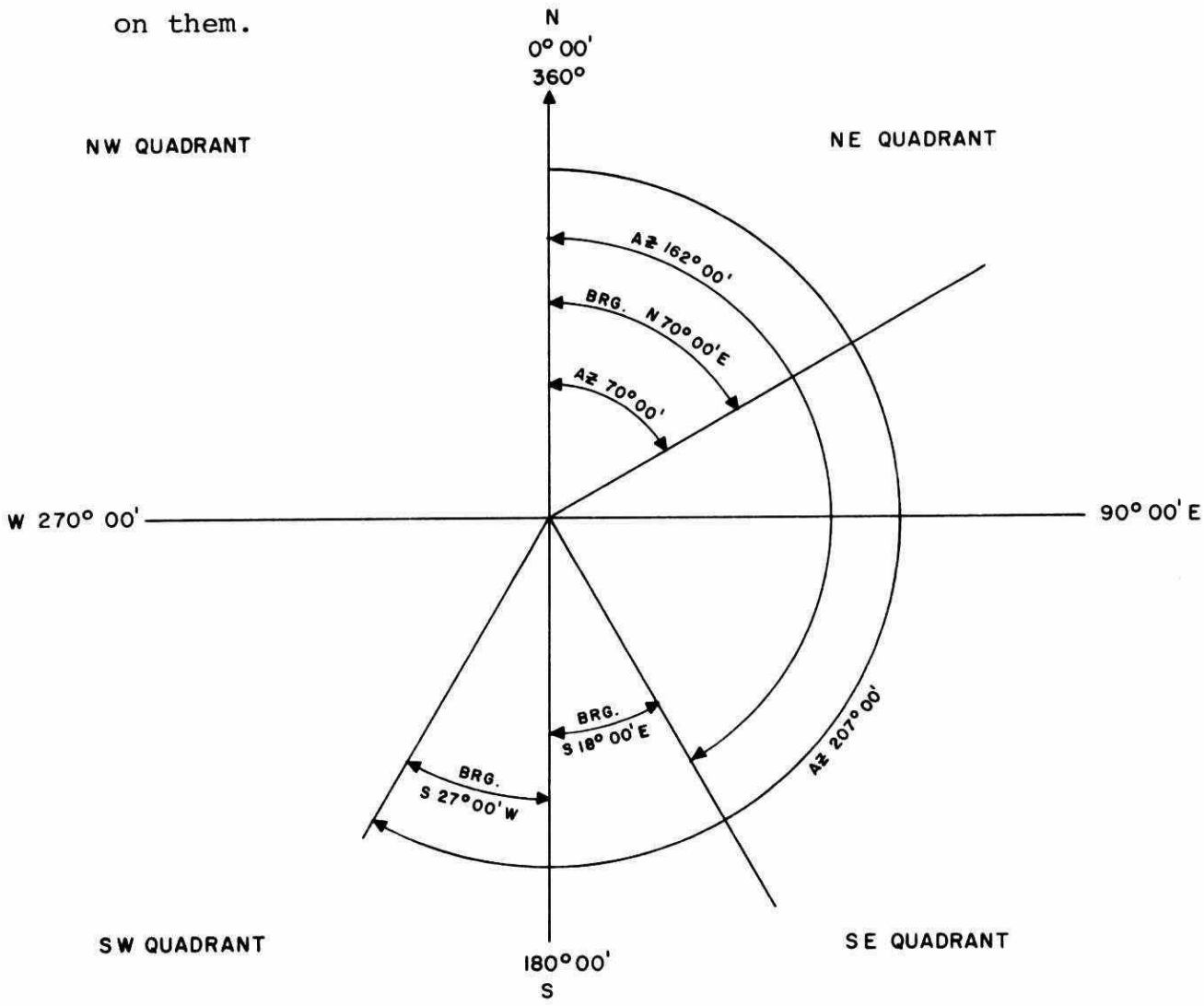
BEARINGS AND AZIMUTHS

The "Azimuth" is the clockwise angle measured from North.

The "Bearing" is the angle measured east and west of north or east or west of south. All readings can therefore by interpreted from a point and fall into four quadrants as follows:

North	- East
South	- East
South	- West
North	- West

All survey plans are referred to a bearing and all boundary lines, street lines, etc., have a bearing shown on them.



APPENDIX - 8E

THE USE OF LASERS IN SEWER CONSTRUCTION

Prepared by Spectra-Physics

INTRODUCTION

Sewer lasers have become an accepted method for providing line and grade control for the laying of gravity flow sewer pipe. Today, you will find that almost 50% of all sewer contractors use sewer lasers.

As inspectors, responsible for the satisfactory construction and completion of a sewer job, it is your responsibility to ensure that accurate line and grade is achieved by the contractor. Therefore, you must understand his methods for achieving line and grade control so that you can do a better job of inspection.

TRADITIONAL METHODS FOR PROVIDING LINE AND GRADE CONTROL

1. Human Eyeball
   - very inaccurate but fast; unacceptable for laying sewer pipe in almost all cases.

2. Carpenter's Level
   - achieve grade control by placing level on each joint of pipe and knowing how much the bubble should be off
   - certainly not very accurate
   - unacceptable for anything but a rough check

3. Batter boards

(2 systems, both referred to as batter boards)

(a) those that span across a trench at regular intervals with nails in the top to give centerline
- measure down, usually an even number of feet, to set invert of pipe at correct elevation
- fairly accurate, acceptable for most underground construction
- but awkward and time-consuming
- not used very much any more.

(b) "boning arms"
- most common of traditional methods
- stakes at regular intervals along side of trench with cross-pieces set at a given number of feet above desired invert elevation
- foreman sights along cross-pieces at a "story pole" that has a cross-piece on it, the same given number of feet above its toe which is resting on the invert of the pipe
- line is usually obtained by measuring over from offset hubs and dropping a plumb bob
- accuracy is generally acceptable, however accuracy attained depends very much on individual doing the sighting.

4. String Lines
- using the offset hubs, string line is set along side of trench at a certain offset from desired centerline of pipe and a given number of feet above desired invert elevation

- line is obtained by measuring over from string line and dropping a plumb bob

- grade is obtained by hanging a string between the story pole and the string line and checking its levelness with a little level vial hooked to the string

- accuracy can vary and it does take time.

5. Survey Instruments

a) Engineers Level
   - generally used to check grade only by setting up at side of trench and "shooting" every pipe, by taking readings on rod held on pipe
   - generally used only where grade is critical or to check other methods.

b) Engineers Transit
   - can be set up behind manhole on line and then on grade by tilting the telescope, so that you can take the same reading on the rod each time
   - requires an instrument man to take shots
   - very accurate, but very expensive having an instrument man there all the time.

SUMMARY

1. These techniques have remained essentially the same for 200 years.

2. Accuracy attained is generally considered acceptable but it is solely dependent upon

the individuals involved. There can be wide discrepancies between crews or between the contractor and the inspector.

3. Usually 2 men are required to check line and grade.

4. These techniques all require a skilled person, usually the foreman, to check line and grade. This takes the foreman away from other important supervisory tasks.

5. Typically, these techniques are time-consuming as well as being cumbersome.

6. Generally, increased productivity can only be attained at the expense of decreased accuracy. This causes the contractor and the inspector to be in conflict.

The advent and acceptance of sewer lasers is a direct response to the disadvantages of these traditional methods.

- most progressive sewer contractors now use sewer lasers to provide line and grade control.

THE USE OF LASERS FOR PROVIDING LINE AND GRADE CONTROL

1. What is a LASER?
   - acronym for L.ight A.mplification by S.timulated E.mission of R.adiation
   - invented in late 1950's
   - can make anything "lase"; carbon dioxide, ruby, etc.
   - laser we use is a low-power gas laser
     - a sealed tube filled with mixture of helium and neon
     - voltage drop created in tube

- excites molecules which then collide and emit photons of light
- a 90% mirror at one end and a 100% mirror at other end
- light emitted is monochromatic light, all of the same wave length and in phase
- therefore a perfectly straight line of light than can be used for alignment purposes
- perfectly safe - will not harm you - simply red light, nevertheless, should not look directly into beam.

2. What is a sewer laser:
   - laser tube packaged in a rugged, waterproof casing with accessories to allow laser beam to be set up coincident with theoretical center-line of pipe
   - runs off of 12-volt battery
   - today, most sewer lasers have features and accessories designed to provide reliability and to facilitate fast, accurate set-ups.

3. Basic procedure for using a sewer laser:
   a) set up sewer laser at beginning of run of pipe
      - dial the Grade to set the laser beam on the desired per cent of grade
      - set the laser beam at the correct height above the desired invert elevation
      - level the laser or allow it to self-level
      - set the laser beam on the desired centerline of the pipe

   b) generally, the laser beam is set up to shoot through the pipe although it can be used over the top of the pipe

c) using special transparent plastic targets set in the bell end of the pipe, the pipe is centered on the laser beam; it is then both on line and on grade

d) can also use the laser beam as reference for keeping the back-hoe on line, checking mud-grade, and checking the bedding.

4. Evolution of Sewer Lasers

- since their introduction in the late 1960's, sewer lasers have gone through several stages of evolution.

1st Generation Sewer Lasers

- such as Spectra-Physic's Model 655 Dialgrade
- analogous to the Model T in cars
- simple, functional, a solution to a problem
- many are still being used today

2nd Generation Sewer Lasers

- such as Spectra-Physic's Model 855 Dialgrade
- introduced in early 1970's
- refinements of earlier models allowing the sewer laser to be set up faster and easier.

3rd Generation Sewer Lasers: Self-Leveling

- such as Spectra-physic's Model 955 Dialgrade SL
- introduced in early 1974 and incorporated a new concept: - electronic self-leveling
- development of self-leveling was a response to a need
- to be able to leave a laser unattended and have confidence in its remaining level
- to know when the laser is moved off grade
- to further reduce time required for set-ups and to save time previously required for checking and adjusting laser occasionally.

5. The Concept of Self-Leveling

a) "automatic" engineers levels are self-leveling
   - uses an optical compensator - a small lens or mirror-like prism that hangs in pendulum-fashion on hair thin wires or is suspended on miniature ball bearings
   - much faster to set up, just rough-level the instrument, the compensator takes care of the rest

b) self-leveling in a laser is even more important
   - you cannot constantly watch it like an instrument to check its level, you must have confidence in it remaining level
   - if it does get knocked off level, there should be a system to warn you when it is not level
   - any self-leveling system in a sewer laser must be fairly rugged because it gets treated like a tool, not an instrument.

c) to develop a reliable self-leveling system for lasers, Spectra-Physics reviewed the known self-leveling methods:
   i) optical compensator
      - fine for instruments but too fragile for lasers
      - very narrow self-leveling range, $\pm$ 1/4^{o}
      - cross-axis rotation reduces accuracy of self-leveling device, due to side friction
      - subject to vibration, difficult to damp

ii) liquid compensator
- difficult to maintain calibration through wide changes in temperature.

After reviewing the needs of the sewer contractor, the requirements for self-leveling in lasers, and the known methods, Spectra-Physics developed a new system - Electronic Self-Leveling.

d) Electronic Self-Leveling
- incorporates solid state electronics and the simplest of all known level indicators, the bubble in a level vial, both of which can absorb a lot of hard knocks

- system is designed to constantly sense the position of the level vial and uses the resulting signal to control an electronic actuator that keeps the laser precisely level at all times.

What Electronic Self-Leveling means for a Sewer Laser

1) a much more rugged, reliable sewer laser
- can take the knocks that it will get on sewer job

ii) a much larger self-leveling range of $\pm 1^{o}$
- faster to set up
- manual corrections do not have to be made as often

iii) no cross-axis sensitivity
- grade accuracy not affected by rotation of laser

iv) vibration free laser beam
- due to inherent damping of electronics

v) not affected by temperature changes
- grade accuracy maintained

vi) Early Warning System can be provided
- laser beam flashes on and off when laser is not level
- so crew will not lay pipe to a bad beam.

APPLICATIONS

Sewer lasers can be used on any job under just about any job-site condition. Different support accessories are generally provided to allow this flexibility. While every sewer job is different, if you know the basic procedures and the most common set-ups, you should be able to solve any situation you encounter.

Basic Procedure - Just remember the four main steps:

1. Dial in the correct per cent of Grade.
2. Level the laser or allow it to self-level.
3. Set the laser beam at the right height.
4. Set the laser beam on the correct line.

1. and 2. are self-explanatory and straight forward.

3. Set the laser beam at the right height.

There are four basic methods recommended to set the Spectra-Physics Model 955 Dialgrade SL laser beam at the correct height above invert.

a) Off the manhole floor - If you are starting out from a precast manhole, already set in place, sometimes you can

simply measure off the manhole floor. If the manhole was set at the right depth, and the thickness of the manhole floor is known, you can work back to the correct laser beam height above invert very easily by holding a wood rule in front of the laser beam. Just set the laser spot at the right distance off the manhole floor. The Dialgrade SL must be set at the correct per cent of grade before using this method.

b) 966 Hi-Line calibrated rods - When using the 966 Hi-Line scope-on-a-pole accessory with your Dialgrade SL, the Hi-Line sighting scope can be rotated to sight a Philadelphia Rod resting on an offset hub. Remember the Hi-Line sighting scope can be rotated 360° on the rod. To set the laser beam height above invert, level the 966 sighting scope and determine HI above the offset hub by taking a reading off the Philadelphia Rod. Add the HI above the hub, to the distance from hub to invert called out on the cut sheet. Then subtract the radius of the pipe I.D. The answer is the distance from the centerline of the Hi-Line sighting scope to the center of the Dialgrade SL laser beam. Using the graduations on the Hi-Line calibrated rods set the laser beam at the correct distance from the center of the sighting scope by using the reference lines and edges that indicate the center of the laser beam on the Dialgrade SL laser head.

c) Philadelphia Rod and engineers level or transit - First set up the Dialgrade SL, over the start point, as previously described. Then determine HI by setting a Philadelphia Rod on the manhole center offset hub and taking a reading. Add the HI and the distance from the hub to invert. The answer is the distance from the centerline of the surveying instrument telescope to the invert of the pipe. From this answer subtract the radius of the pipe I.D. and 174mm (the distance from the top of the Dialgrade SL mounting bracket to the center of the laser beam). The

answer is the correct distance from the centerline of the surveying instrument telescope to the top of the Dialgrade SL mounting bracket. Now set the Philadelphia Rod on the reference mark on top of the Dialgrade SL mounting bracket. Take a reading. Compare this reading with the previous step and adjust the Dialgrade SL up or down as required using the calibrated vertical pole.

d) Tapeing from a batter board - If an engineer's level or transit is not handy, depth to invert can be obtained easily by installing a batter board over the center of the manhole. Measure down from the batter board edge to the top of the Dialgrade SL mounting bracket with a plumbed tape measure. The correct distance is the distance from the batter board edge to invert less the radius of the pipe I.D., less 174mm from the center of the laser beam to the top of the Dialgrade SL mounting bracket.

4. Set the laser beam on the correct line.

Two points are needed to define a line. For sewer lasers, the two points are generally determined by referring to the offset hubs previously placed. These may be the offset hubs for the manhole centers or even the offset hubs between manholes set to maintain line.

There are three basic methods recommended to set the Dialgrade SL laser beam on line.

a) Dropping plumb lines, measured over from offset hubs.

This method is similar to the methods used to set the centerline of pipe, when using batter boards and string lines. First, determine

the start point, or the position of the laser, by measuring over from the offset hub, the offset distance and drop a plumb bob. The tape or pole used to measure over should be level and at 90^{o} to the flowline to give a correct measurement.

A second point, at least 6m away from the first, is then determined using the same method. Then the laser beam is aimed at the second point using the tangent adjustment. Usually, 6m or so of trench must be excavated first in order to set the second point.

Line should then be checked when 30m or so of pipe has been laid so that any final adjustments can be made to the line of the laser beam.

b) Engineers Transit

An engineers transit can be "bucked in" on the desired centerline of the pipe behind the start point of the run of pipe. Then, sighting through the transit, the instrument man can first help locate the laser over the start point and then give a second point at which the laser beam can be aimed. Sometimes an engineers transit can be set up directly over the start point using an accessory known as a "manhole mount". Then it is merely a matter of determining the second point with transit. This method is explained in greater detail below in the section on different set-ups.

c) Using the Spectra-Physics 966 Hi-Line Accessory

This accessory system is designed to allow the telescope, used for giving line, to be mounted on the same axis as the laser. Therefore, when the telescope is adjusted to be on line, the laser is automatically put on line. This system is explained in greater detail below in the section on different set-ups.

Most Common Set-ups

1. Trivet Plate
   - the most commonly used set-up by far
   - simplest and quickest to set up

   - can be used in - precast manholes with solid bases
     - large diameter pipes
     - open excavations with proper support.

MODEL 932 TRIVET PLATE ON A MANHOLE FLOOR

The 932 trivet plate is the fastest way to set up the Dialgrade SL in a precast manhole. The trivet plate has a three screw level system and a calibrated pole with a bullseye level on the top. You should think of it as a baseplate and vertical pole all in one piece. A line adjustment knob is built into the trivet plate that rotates the pole to put the Dialgrade SL laser beam on line.

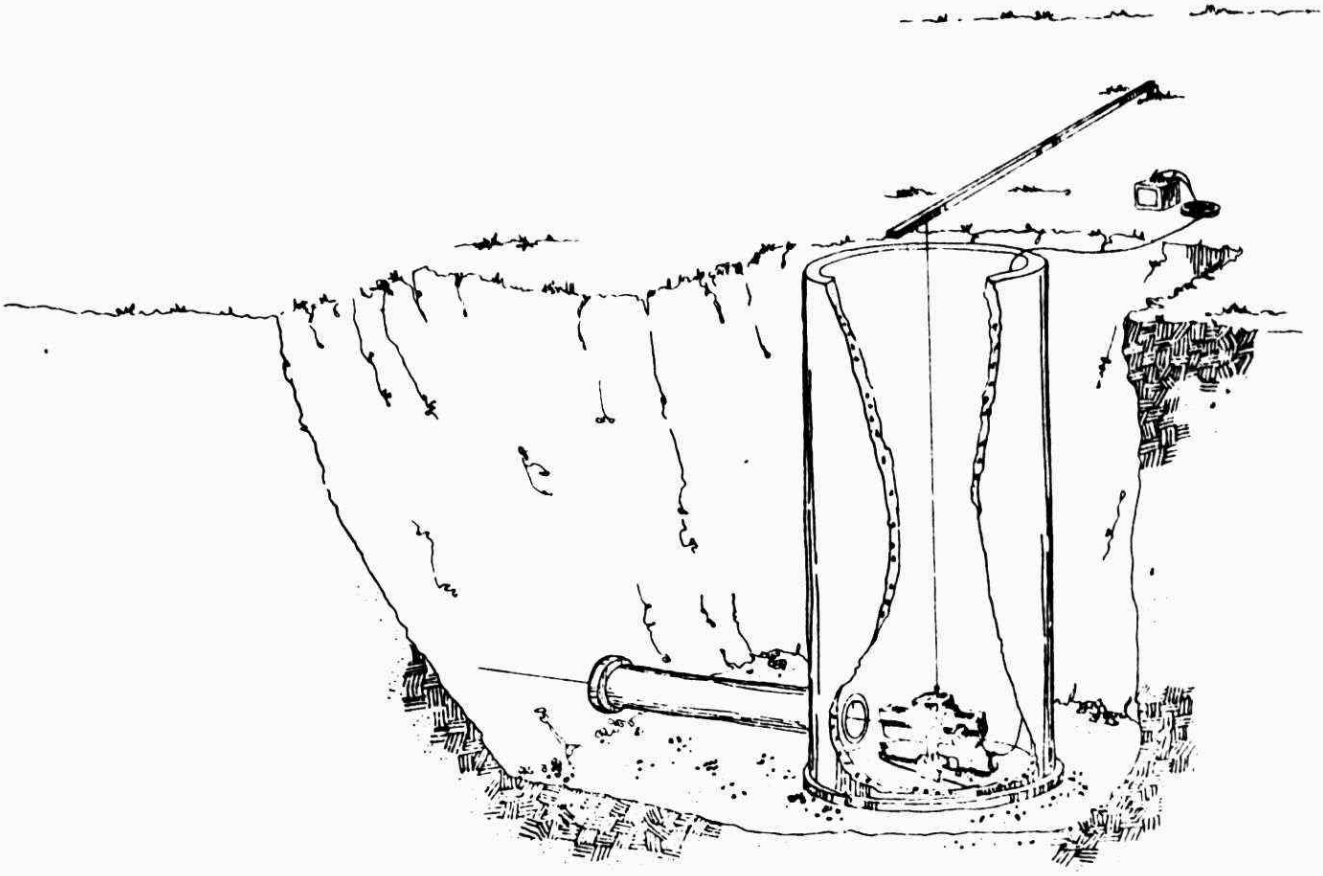


Figure 8E-1

The 932 is set on the flowline the same way the baseplate is. When the Dialgrade SL is clamped to the trivet plate pole the center of the laser beam is automatically over the rotation point of the pole.

The trivet plate is calibrated from the top down. So when you set a Philadelphia Rod on top of the pole the graduations read downward off the end of the Philadelphia Rod. This makes it easier to determine laser beam height above invert. The Philadelphia Rod can also be set on top of the Dialgrade SL mounting bracket as described in Using the Dialgrade SL section.

Determine line with a stringline and plumb bob, transit on a 607 manhole mount, etc., as described in Using the Dialgrade SL and Major Accessories section. "Dial in" per cent of grade and go to work laying pipe.

The weight of the trivet plate and Dialgrade SL combination plus the plumb bob points on the leveling feet make this setup very stable.

MODEL 932 TRIVET PLATE FOR LARGE PIPE

The 932 is the fastest way to set up in large pipe. The trivet plate simply rests in the invert of the pipe like it does on a manhole floor.

Set up is the same as the procedure for a manhole floor. However, there is a trick or two that makes large pipe set ups with the 932 trivet plate a snap.

The 932 can also be set on cement blocks in front of the first joint if you prefer to set the first joint of pipe with the laser beam. Finding flowline and determining laser beam height above invert is done as described in Using the Dialgrade SL and Major Accessories section.

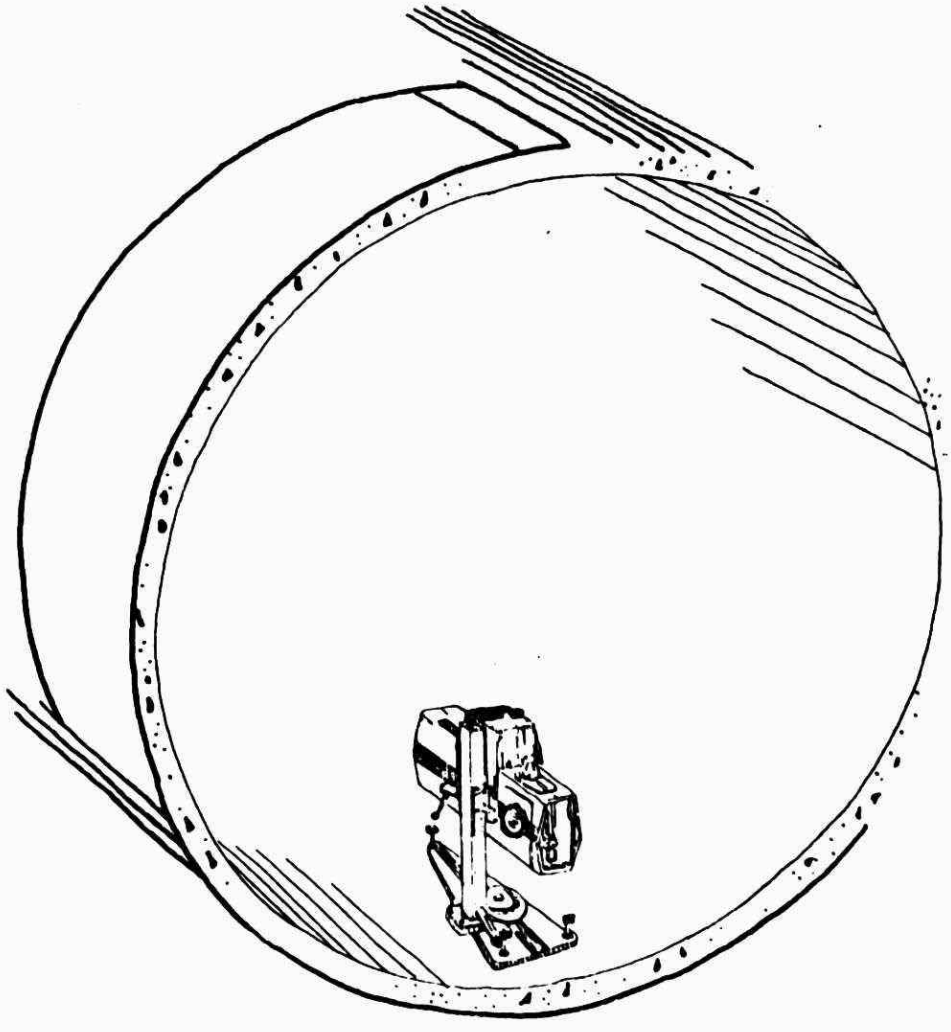


Figure 8E-2

2. Vertical Poles and Cross-Arm Braces
   - provides a much more stable set-up
   - can be used in - drop manholes or poured invert manholes
     - manholes with solid bases
     - large diameter pipe
   - can be combined with the 966 Hi-Line Accessory to provide a simple way to determine line.

MANHOLE WITH POURED INVERT OR RAISED INVERT

If a concreted round invert has been poured in your manhole floor or if a raised invert is required you can still use the Dialgrade SL and get a perfect job.

Hang a stringline and plumb bob down the center of the manhole opening. This provides a centerline reference that makes it easier to line up crossarm braces, clamp adjusters and the vertical pole before making final adjustments.

Set the crossarm braces in place so that they just touch the stringline and are parallel when looking down on them from above. They should be set about 1m one above the other. (However, they can be set farther apart when using 966 Hi-Line.)

Assemble a Hi-Line clamp adjuster to each crossarm brace. Align the Hi-Line clamp adjusters on the crossarms so that you can look down through the square vertical pole holes to an imaginary point 63mm to the left of the flowline of the poured invert, when facing the direction the pipe will be layed.

Assemble a vertical pole or stack of Hi-Line rods through the Hi-Line clamp adjuster.

If the set up is for a poured invert the vertical poles should be pushed down against the side of the invert with the steel point on the bottom rod touching the concrete.

If the dual crossarm brace set up is for a raised manhole invert the crossarms should be positioned so that the laser beam height above the invert falls between the crossarms so that the Dialgrade SL can be clamped on between them.

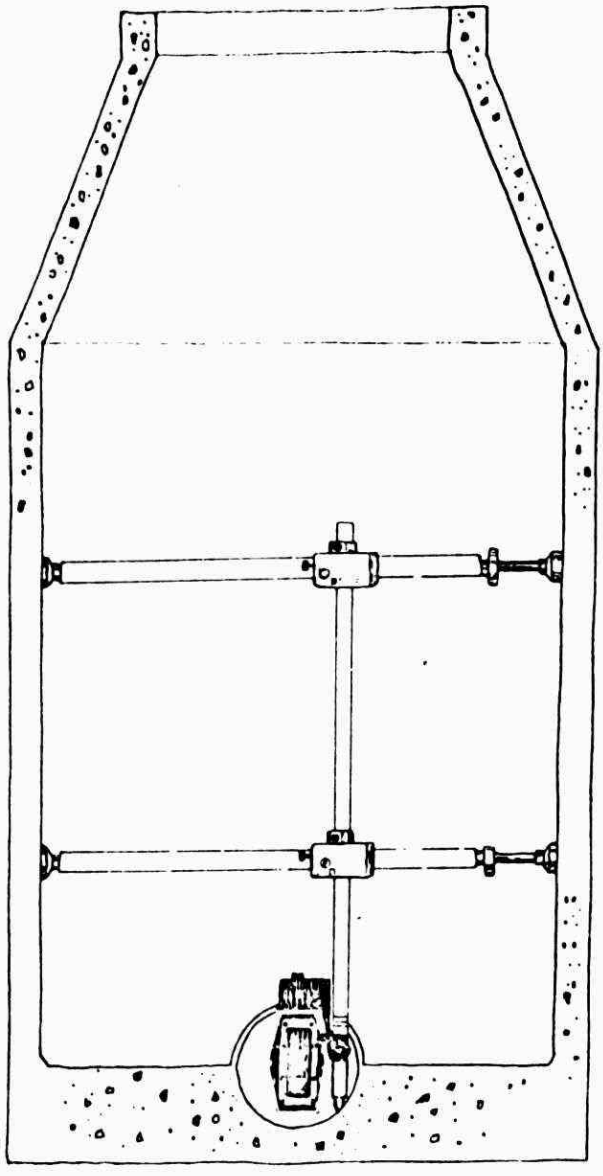


Figure 8E-3

If the 966 Hi-Line Accessory is used with two crossarm braces the bottom Hi-Line clamp adjuster must freely rotate when adjustments for line are made with the top Hi-Line clamp adjuster.

Now the vertical pole or Hi-Line rods must be plumbed and adjusted so that the Dialgrade SL laser beam will be on flowline. This is usually done by simply measuring the center of the poured invert as cast in the floor and setting up the laser beam to that point on the flowline. Now get another point on the flowline up ahead and adjust the laser beam to split it. See Using The Dialgrade SL section.

With a raised manhole invert, start point is in space. Consequently, a stringline and plumb bob must be dropped that is centered on flowline. The vertical pole hanging in space must be adjusted so that it is plumb and parallel to the stringline and 60mm on the left side of it facing the direction the pipe will be layed. When the Dialgrade SL is clamped to the vertical pole the laser beam will be on the flowline of the raised invert. Beam height above invert and final line adjustments can now be determined using the methods outlined in Using The Dialgrade SL section.

These set ups are very rigid and give excellent stability. The Dialgrade SL with electronic self-leveling gives you perfect grade insurance in these two tough set up situations.

MANHOLE WITH SOLID BOTTOM

We have already discussed use of the Dialgrade SL with the 966 Hi-Line Accessory in the section on Using Major Accessories. The Dialgrade SL can also be set up in a man-

hole using only a short vertical pole, one crossarm brace and a baseplate.

1. Start with a point along the center of the pipe. Place the baseplate over the start point.

2. Only one side of the crossarm brace extends. Hold one side against the manhole wall and extend the other end until it contacts the opposite side. The speed nut on the crossarm brace makes it fast and easy.

3. Assemble the Hi-Line clamp adjuster to the crossarm brace. Sight down through the square hole in the clamp adjuster and align it with the hole on the left edge of the baseplate as you look toward the direction the pipe will be layed.

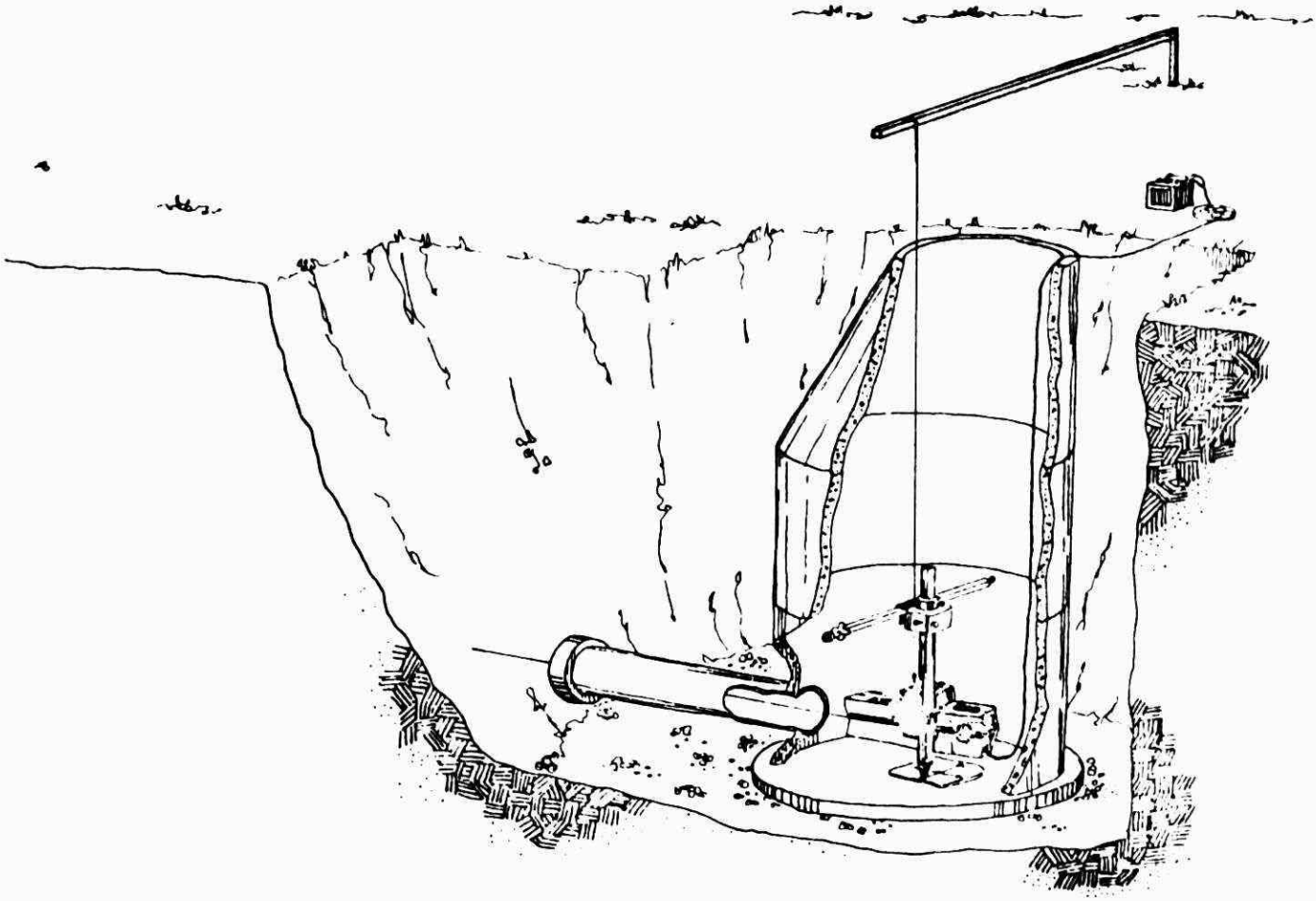


Figure 8E-4

4. Set the vertical pole in the baseplate. Secure the vertical pole to the crossarm brace with the Hi-Line clamp adjuster. Plumb the vertical pole using the bullseye level on top for reference. This is done by moving the crossarm brace and sliding the Hi-Line clamp adjuster back and forth.

5. With the crossarm brace set in place and the Hi-Line clamp adjuster and vertical pole assembled it is a very solid set up.

6. The Hi-Line clamp adjuster provides 360° rotation and $\pm 10^{\circ}$ fine line adjustment.

7. Obtain laser beam height above invert and get the laser on line using techniques outlined in **Using The 955 Dialgrade SL** section.

CROSSARM BRACES IN LARGE PIPE

The same crossarm brace used in a precast manhole setup also works in large pipe. Crossarm braces can be cut as short as 575 mm if desired. The standard crossarm brace works in 1200 to 1500 mm diameter pipe.

If pipe larger than 1500 mm is being layed set the crossarm brace against a 100 x 100 timber put vertically in the pipe.

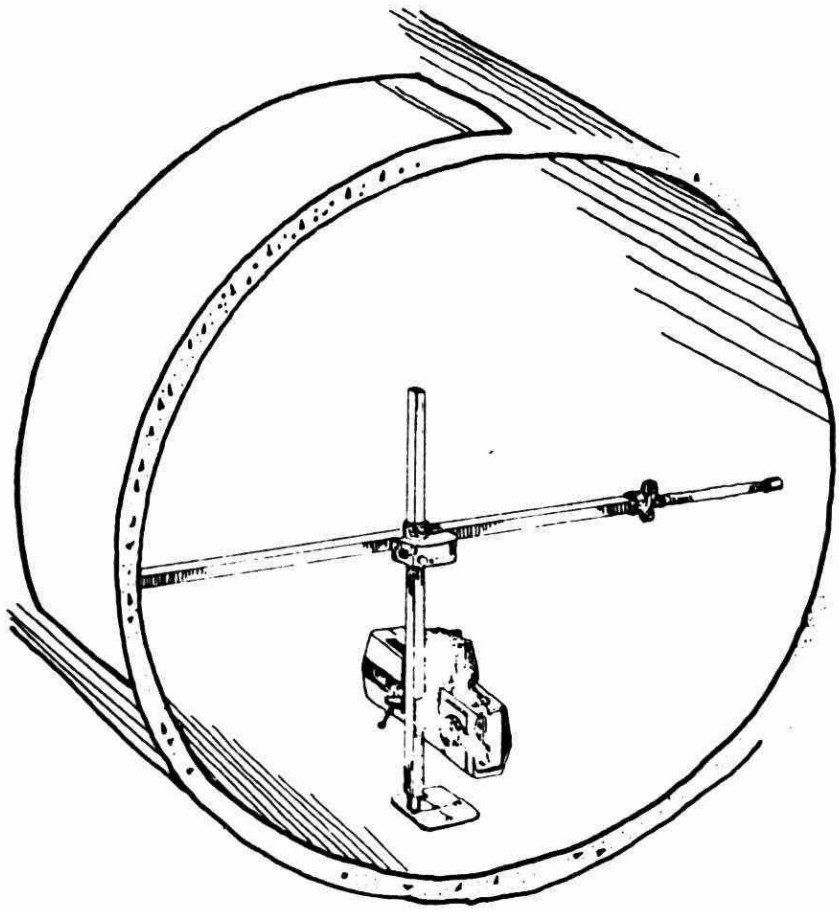


Figure 8E-5

The first step is to establish a start point in the first joint of pipe. If a transit is available just set the Dialgrade SL baseplate on flowline by lining it up with the vertical crosshair of the transit. If a transit is not available tie a stringline and plumb bob around the center of a small carpenter's level, just like the one you would use for batter boards. Level the carpenter's level on a chord across the upper ID of the pipe. The plumb bob will hang to the flowline of that joint of pipe. Mark the point and set the baseplate over it. Attach a crossarm brace over the baseplate and install the Hi-Line clamp adjuster sliding it until the square hole is over the proper hole in the baseplate. Install a vertical pole and adjust it plumb. Clamp the Dialgrade SL on the vertical pole. "Dial in" per cent of grade. Set the laser beam to the desired height above invert and get it on flowline using the methods described in Using The Dialgrade SL section.

Take a large pipe target to the other end of the pipe. Level the target in the invert and adjust the bullseye on the target to the same height as the laser beam. Remember the laser beam is already on line and grade. Now your target is set up to lay the remaining pipe.

There are many variations to setting up in large pipe. If you need to keep the pipe floor clear for such things as pipe jacks use two crossarm braces and two Hi-Line clamp adjusters and suspend the laser in the roof of the pipe. Remember the large pipe target can be turned upside down and set on the bell of the pipe.

HI-LINE ACCESSORY SETUP PROCEDURE

The basic setup techniques in the Using Dialgrade SL section remain the same. The Hi-Line Accessory expands the overall utility of the Dialgrade for those contractors who

prefer the scope on the pole setup. The manhole and open excavation setup illustrations depict two of the most common applications for the Hi-Line Accessory. The basic alignment steps for both of these set up situations are as follows:

STEP NO. 1

The Hi-Line Accessory sighting scope can be rotated to sight on an offset hub for determining HI just by unlocking Knob 1. The sighting scope will now rotate 360° horizontally. There is no necessity for unlocking the rod or taking the scope off the rod sitting on the baseplate. Place a Philadelphia Rod on the manhole center hub. Level the Hi-Line sighting scope and take a reading to determine HI. Add the HI to the distance from the centerline of the sighting scope to the invert of the pipe. Then subtract the radius of the pipe I.D. Now you have the desired distance from the centerline of the sighting scope to the laser beam center. Using the calibrated rods set the Dialgrade SL beam at the determined distance.

STEP NO. 2

After assembling the Dialgrade as illustrated, making sure the calibrated rods are plumb, it is then necessary to sychronize the Dialgrade laser head and the Hi-Line Accessory sighting scope. First, excavate a metre or so of trench. Find the laser beam hitting the back of the cut and adjust the Hi-Line sighting scope, Knob 2, until the vertical crosshair splits the laser beam. If the beam is difficult to see in the dirt use a pipe target or shovel to enhance beam visibility in the ditch.

STEP NO. 3

Next plunge the sighting scope down on the Dialgrade laser head and use the lateral fine adjust knob, Knob 3, to adjust the sighting scope so that the vertical crosshair splits the black line reference mark on the top front end of the Dialgrade.

STEP NO. 4

Recheck the alignment of the laser beam in the trench by repeating STEP NO. 2 and make a fine adjustment if necessary. The Dialgrade laser head and the Hi-Line sighting scope are now synchronized in the same vertical plane.

STEP NO. 5

Sight on the next manhole and align the sighting scope vertical crosshair with the manhole center by using the horizontal fine adjust knob on the Hi-Line clamp adjuster, Knob 2. Since the Laser head is synchronized to the sighting scope the laser beam is now on line.

SIX SIMPLE STEPS TO REMEMBER

1. Determine laser beam height above invert.

2. Plumb the rods.

3. Sight in the trench.

4. Sight down on the laser head reference mark.

5. Resight in the trench.

6. Sight on the next manhole center.

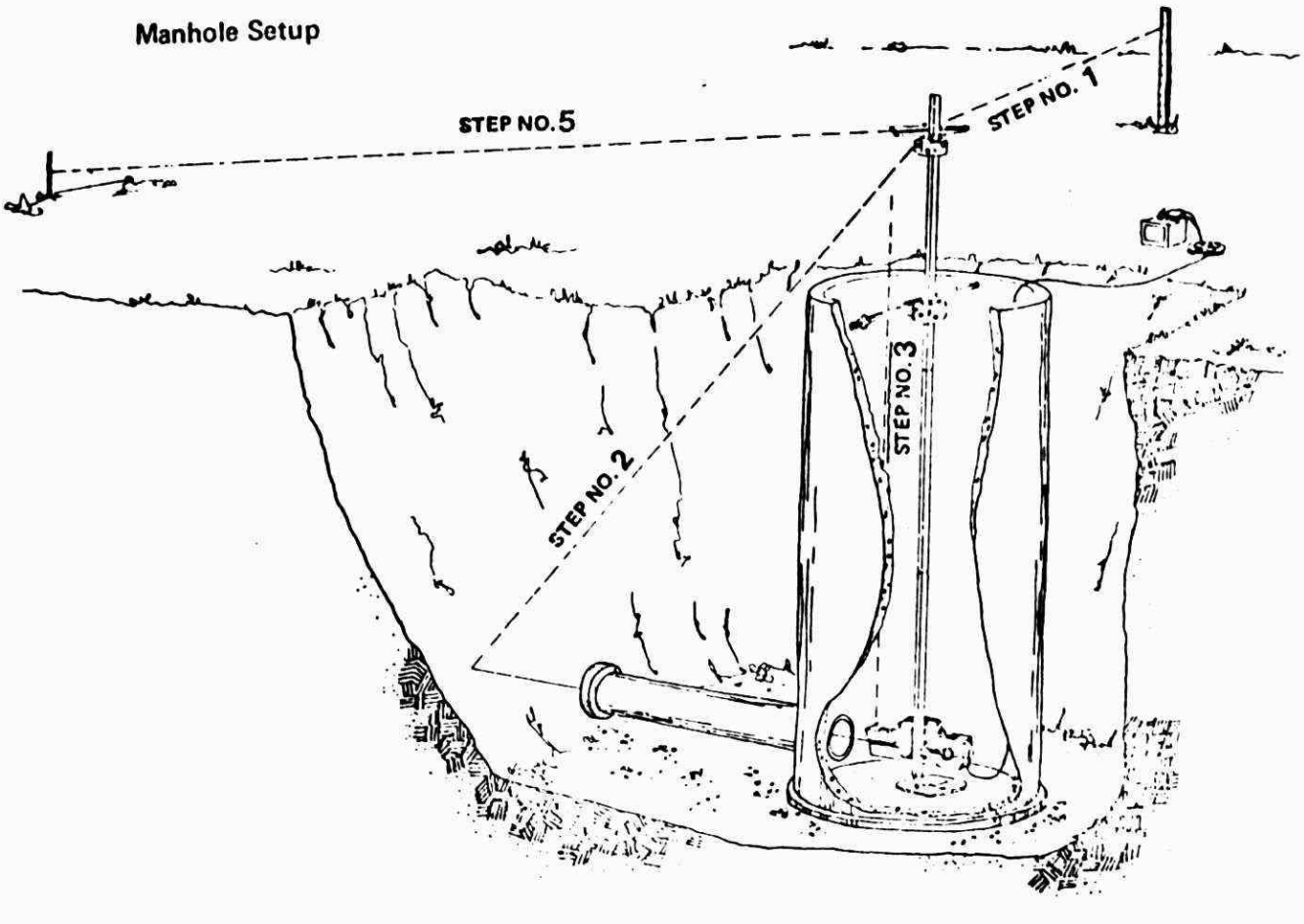


Figure 8E-6

3. Manhole Mount

- the manhole mount accessory can be used to

set up either an engineers transit or the 966 Hi-Line Accessory Sighting Scope directly over the start point.

MODEL 607 MANHOLE MOUNT WITH 966 HI-LINE SIGHTING SCOPE AND ADAPTOR

In those situations where the complete 966 Hi-Line Accessory cannot be used, such as a very deep manhole, or because of personal preference the Model 868 adaptor can be used that permits use of the 966 Hi-Line sighting scope on the Model 607 manhole mount.

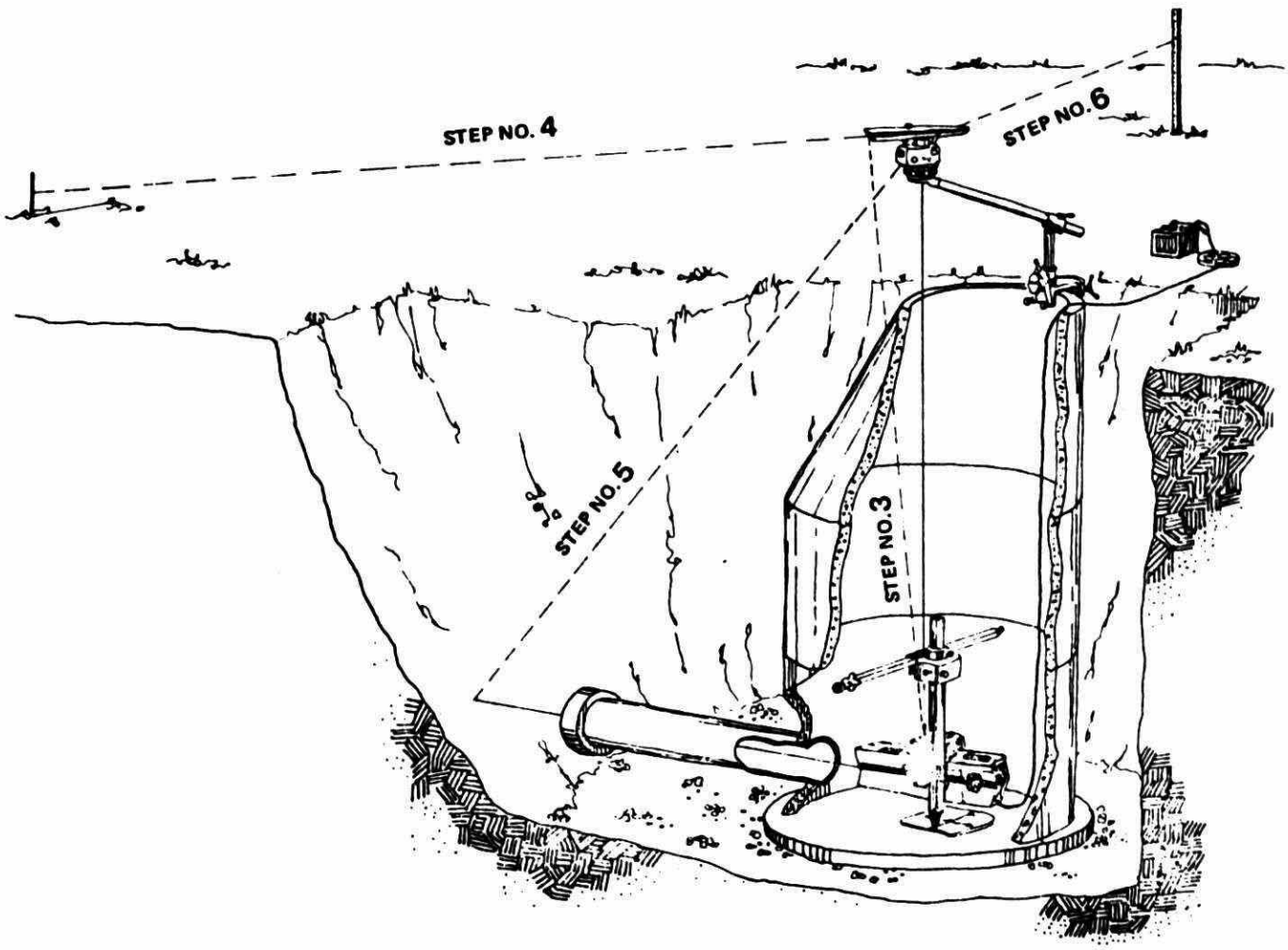


Figure 8E-7

The procedure for using this is to first set up the Dialgrade SL over the start point as previously described. Then adjust the 607 manhole mount adaptor and Hi-Line sighting, so the scope is directly over the reference mark on the top of the Dialgrade SL mounting bracket. This is done by:

STEP NO. 1

Hang a plumb bob down from the offset wing of the adaptor over the reference mark on top of the Dialgrade SL mounting bracket.

STEP NO. 2

Plumb the Hi-Line sighting scope adaptor using the bullseye level on top of it. The manhole mount adjustment clamps give all axis freedom. Make sure the plumb bob is still over the reference mark when finished with this step.

STEP NO. 3

Plumb the vertical crosshair of the Hi-Line sighting scope using the lateral fine adjust knob No. 3. This is done by sighting down the plumb bob string hanging down to the laser or by having someone hold a plumb string on the side of the ditch for you to sight on.

STEP NO. 4

Sight on the next manhole center and lock up the Hi-Line sighting scope so the vertical crosshair splits it.

STEP NO. 5

Plunge the Hi-Line sighting scope into the trench approximately 25 feet ahead and adjust the Dialgrade SL laser beam, using the fine adjust knob No. 2 on the Hi-Line clamp adjuster, until the beam splits the vertical crosshair of the scope.

STEP NO. 6

Find laser beam height above invert as described in using the Dialgrade SL section.

You now have the laser beam on line. With the Hi-Line sighting scope locked on line it can be used as a line check until you arrive at the next manhole. Remember the 607 manhole mount has the same thread so that it can be used with any engineers transit.

4. Tripod Set-ups

- the Dialgrade sewer laser can also be set up in an open excavation using a tripod, a vertical pole and an adaptor
- the 966 Hi-Line Accessory can also be used with the tripod set-up.

OPEN EXCAVATION WITH A TRIPOD

If your precast manholes didn't arrive on time, you don't need to worry with the Dialgrade SL. Just set up with the Dialgrade SL tripod in the open excavation you have to dig for the manhole anyway.

Now establish a start point on flow line. Place the baseplate over the start point with the center groove lined up parallel to flowline. Step down hard on the baseplate to anchor it in the earth.

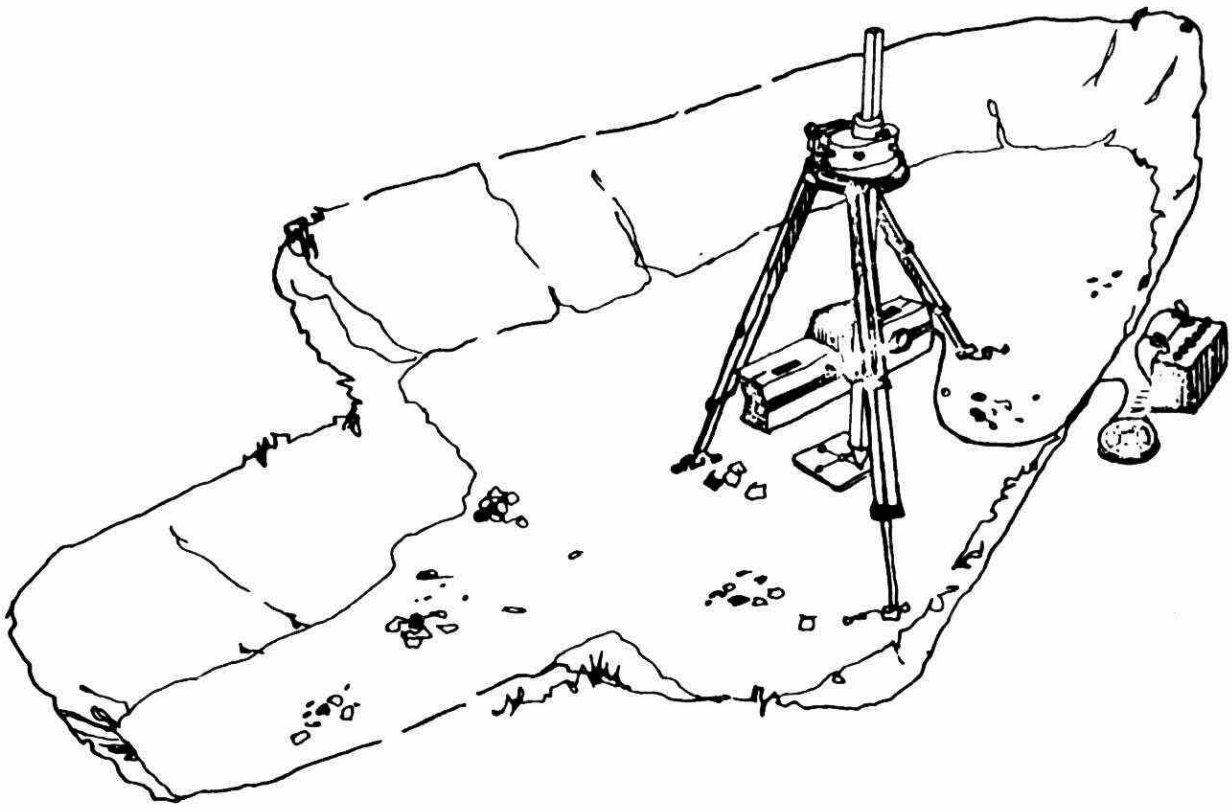


Figure 8E-8

Fasten the Hi-Line clamp adjuster to the tripod.

Now set the tripod and clamp adjuster over the hole on the left edge of the baseplate as you face the direction the pipe is being layed. Look down through the square hole in the clamp adjuster to eyeball align it with the baseplate. This usually involves moving the tripod legs around.

Slide the vertical pole through the square hole in the clamp adjuster and put the steel point on the end of the vertical pole in the proper hole in the baseplate.

Now plumb the vertical pole by sliding tripod legs or the clamp adjuster on its bracket. The bullseye level or pole level make this task easy for you.

Now attach the Dialgrade SL to the vertical pole. Find line and beam height above invert as explained in Using The Dialgrade SL section. Your Dialgrade SL is now providing you with electronic self-leveling grade insurance in an open cut on a tripod.

HI-LINE ACCESSORY SETUP PROCEDURE - FOR TRIPOD SET-UP

The basic setup techniques in the Using Dialgrade SL section remain the same. The Hi-Line Accessory expands the overall utility of the Dialgrade for those contractors who prefer the scope on the pole setup. The manhole and open excavation setup illustrations depict two of the most common applications for the Hi-Line Accessory. The basic alignment steps for both of these setup situations are as follows:

STEP NO. 1

The Hi-Line Accessory sighting scope can be rotated to sight on an offset hub for determining

HI just by unlocking Knob 1. The sighting scope will now rotate 360° horizontally. There is no necessity for unlocking the rod or taking the scope off the rod sitting on the baseplate. Place a Philadelphia Rod on the manhole center hub. Level the Hi-Line sighting scope and take a reading to determine HI. Add the HI to the distance from the hub to the invert of the pipe. The answer is distance from the centerline of the sighting scope to the invert of the pipe. Then subtract the radius of the pipe I.D. Now you have the desired distance from the centerline of the sighting scope to the laser beam center. Using the calibrated rods set the Dialgrade SL beam at the determined distance.

STEP NO. 2

After assembling the Dialgrade as illustrated, making sure the calibrated rods are plumb, it is then necessary to sychronize the Dialgrade laser head and the Hi-Line Accessory sighting scope. First, excavate a few feet of trench. Find the laser beam hitting the back of the cut and adjust the Hi-Line sighting scope, Knob 2, until the vertical crosshair splits the laser beam. If the beam is difficult to see in the dirt use a pipe target or shovel to enhance beam visibility in the ditch.

STEP NO. 3

Next plunge the sighting scope down on the Dialgrade laser head and use the lateral fine adjust knob, Knob 3, to adjust the sighting scope so that the vertical crosshair splits the black line reference mark on the top front end of the Dialgrade.

STEP NO. 4

Recheck the alignment of the laser beam in the trench by repeating STEP NO. 2 and make a fine adjustment if necessary. The Dialgrade laser head and the Hi-Line sighting scope are now synchronized in the same vertical plane.

STEP NO. 5

Sight on the next manhole and align the sighting scope vertical crosshair with the manhole center by using the horizontal fine adjust knob on the Hi-Line clamp adjuster, Knob 2. Since the Laser head is synchronized to the sighting scope the laser beam is now on line.

SIX SIMPLE STEPS TO REMEMBER

1. Determine laser beam height above invert.

2. Plumb the rods.

3. Sight in the trench.

4. Sight down on the laser head reference mark.

5. Resight in the trench.

6. Sight on the next manhole center.

Open Excavation Setup

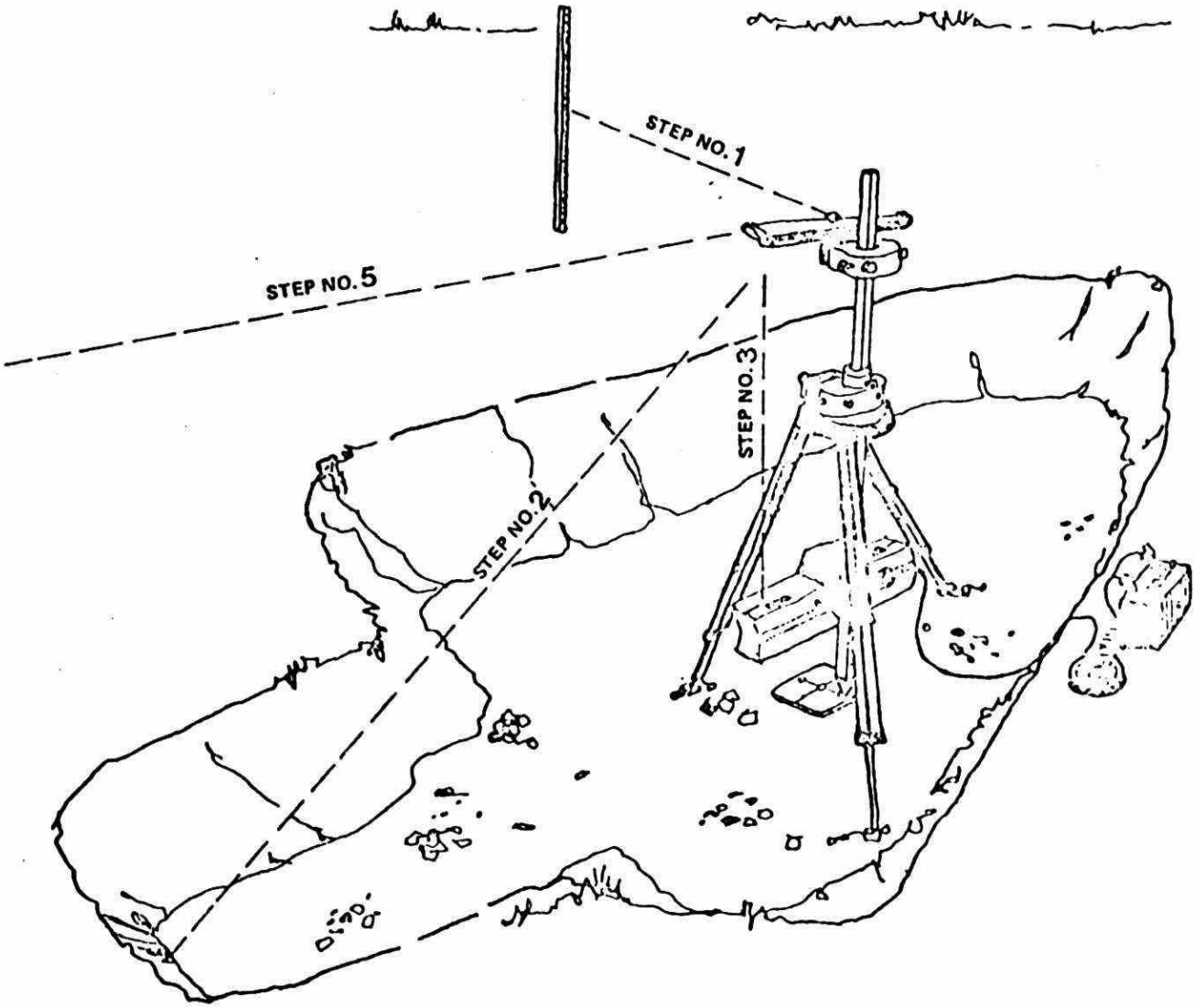


Figure 8E-9

SUBJECT OF SPECIAL INTEREST TO USERS OF SEWER LASERS

Refraction

The Dialgrade SL laser beam is a perfectly straight line of coherent light. Coherent light means it is concentrated in a small diameter and will not diffuse or spread out except at great distance. The fundamental optical principles of reflection and refraction of light also apply to laser light. One of these principles - refraction, can have an effect on the laser beam. Refraction is simply the bending of light at the interface of two substances caused by a difference in the speed of light. Have you ever had the experience of reaching down into water for an object only to find that you grabbed for it in the wrong place? Your aim was fooled by the light refraction between air and the more dense water. The same thing can happen to a laser beam inside a pipe. When air densities in confined places like a pipe line occur due to temperature changes (warm air is less dense than cold air) the laser beam will move usually downward. Air density changes, usually in small pipe, are caused not only by temperature but also by gases and solvents. The vapor from plastic pipe cement, and exhaust gases from a pump or tamper that get temporarily sucked up the pipe cause air density changes.

Refraction of sewer pipe lasers is generally a seasonal thing. The hot summer months is when to look out for it.

The most common cause of laser refraction in a pipeline is installing hot pipe, that has been sitting in the sun at the edge of the trench, into the cool earth at the bottom of the trench. The cool earth immediately begins cooling the underside of the pipe. The air density in the lower half of the pipe changes as the air cools. As the

pipeline gets longer the condition gets steadily worse (usually 50 to 60 m out). The beam begins to flame on the edges or droop off toward the invert of the pipe. Remember this condition occurs only because of air density changes in the pipe. So look out for hot pipe in a cool ditch, cool pipe left un-backfilled over a cool night followed by a very hot day with sun shining down on the pipe, a pipelayer slopping excessive cement on joints of plastic pipe or a pump exhaust pointing at the pipe opening. Here are some ways to alleviate these problems:

1. Keep pipe out of the sun if possible.

2. Lay the pipe hot side down.

3. Backfill as soon as possible.

4. Do not slop excessive plastic pipe cement on each joint that gets squeezed into the pipe when a joint is shoved home.

If the above steps do not work use your Blower to re-establish constant air density in the pipe. Sometimes it may take 10 minutes to blow out 80 to 100 m of 300 mm sanitary sewer pipe.

Model 809 Blower

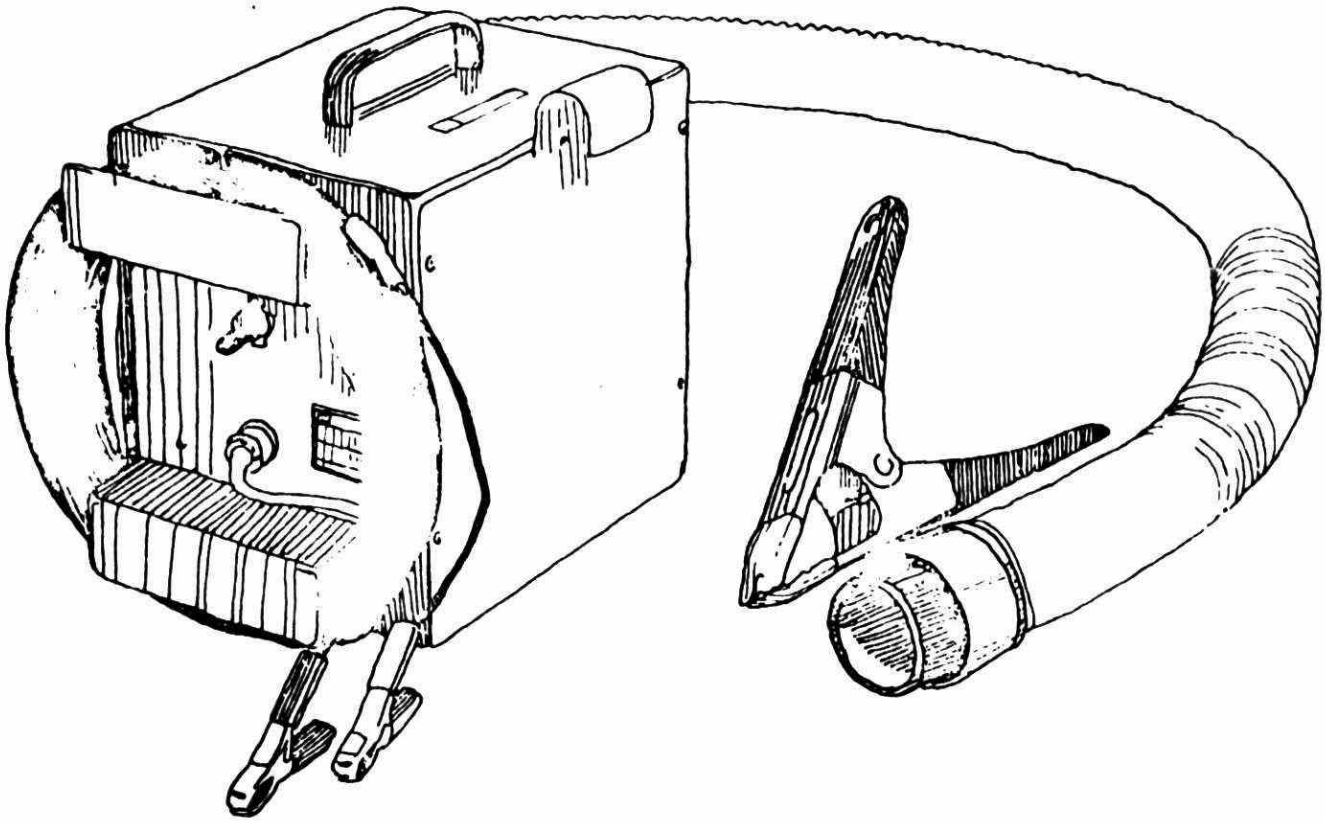


Figure 8E-10

Refraction usually occurs only in small pipe. However, the condition has been witnessed in sizes up to 1200mm. This is very rare. If refraction occurs in large pipe a larger blower such as a Homelite Model 111B gasoline engine driven unit may be required.

To use Model 809 Blower poke into the end of the pipe and secure with the large alligator clamp provided.

Connect the battery clip on the blower power cord to a vehicle battery. Red clip goes to positive battern terminal. Turn on the blower with the on/off switch provided. Fasten the blower to a manhole step with the leather straps to keep it out of the water.

Calibration

It is very easy to check calibration of the Dialgrade SL by double-leveling. The only equipment you need is an engineering rule, the laser head, 932 trivet plate and a battery. Here are the steps:

1. Select a road or field that is fairly level. (It does not have to be truly level, but should not rise more than 100 mm in 15 to 30 m, or the spot will hit the ground.)

2. Designate two points on the ground approximately 30 m apart with a felt tip pen, pencil, or by driving a nail. The distance does not have to be measured. Mark the two points with paint or two tin cans so you can later find them easily.

3. Dial zero grade. Set the laser on the 932 trivet plate or tripod and vertical pole just behind the point lowest in elevation. Connect it to a battery. Aim the beam so it is passing over the two points. (If you do not have a fairly level area, run the test with the laser raised up on a sturdy box at the low end; or mount it on the Vertical Pole supported by the tripod.)

4. Check that the grade indicator is set to zero (level). Allow The Dialgrade SL to self-level.

5. Measure the distance from each point on the ground to the beam center. These distances are shown as A_1 and B_2.

6. Move the laser behind the second spot and repeat the two measurements. These are B_2 and B_1.

7. If the level vial is accurate, then the beam will be truly level with respect to the earth. Hence, the two beams will be exactly parallel to each other at both test positions. Subtracting A_1 and B_1 should give you a number the same as A_2 and B_2 (to within 3 mm. If you were working on a truly level road, all readings would be the same, and the two differences would equal zero.

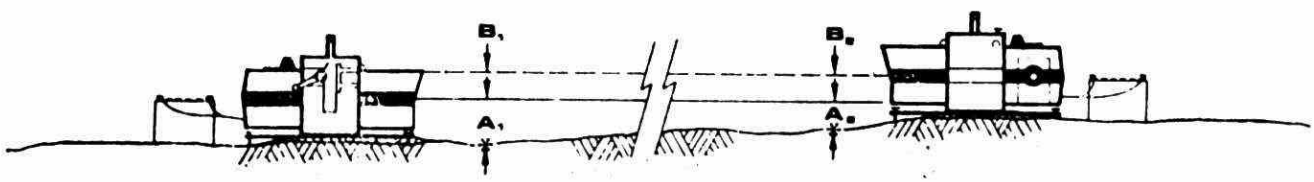


Figure 8-11

SAMPLE SPECIFICATIONS FOR LASER CONTROL ON SEWER CONSTRUCTION

Line and Grade Control

The engineer shall lay out the job by providing an offset hub at each manhole location. The engineer shall provide cut sheets for the contractor's use in executing the work. The cut sheets shall show the amount of cut from hub elevation to pipe invert elevation at each hub. Also, the cut sheet shall show the amount of grade in per cent for each section of pipeline.

In executing the work, the contractor shall utilize a laser instrument in conjunction with the engineer's layout work. The grade instrument used shall have the grade indicator dial graduated to read directly to 0.01% grade with interpolation possible to 0.001% grade. The instrument shall be a factory-built, quality-controlled, precision instrument, capable of controlling grade to a tolerance of plus or minus 0.01% grade through a grade range of - 10% to + 20%.

The laser for the grade instrument shall be provided with a collimating lens system capable of producing a spot no larger than 19mm in a working range of 0 to 150m. The intensity of the beam shall not exceed 5.0mw. The laser tube, electronics, collimating optics, and grade device must be contained inside a waterproof enclosure.

Alignment of the grade instrument shall be controlled by either a sighting scope internal to the laser head and aligned to the beam or a transit placed on line such that line is set into the laser by referencing the transit and laser head to the forward manhole location.

The grade instrument shall initially be adjusted to the proper height to sheet through the pipe by transferring the cut from the engineer's offset hub to a reference point on the grade instrument.

Trench line and grade, also grade for select bedding if required, shall be controlled by observing the laser beam with reference to a mark on a hand shovel, or other suitable target. The laser beam may be placed either at the level of the pipe or above the ground. If placement is at pipe level, each section of pipe shall be placed to line and grade by inserting a pipe target into each pipe and adjusting the pipe until the beam strikes the target at the proper index. If the laser is placed above ground a story pole with an integral plumbing device to intercept the laser beam shall be used.

Line and Grade Control

The engineers will lay out the job by providing an offset hub at each manhole location. The engineers will provide cut sheets for the contractor's use in excavating the work. The cut sheets shall show the amount of cut from hub elevation to pipe invert elevation at each hub. Also, the cut sheets shall show the amount of grade, in per cent, for each section of pipeline.

In executing the work, the contractor shall utilize a laser instrument in conjunction with the engineer's layout work. The grade reading device associated with the laser instrument shall be mounted internally in the system to protect against damage and shall be graduated to read directly to 0.010% grade with interpolation possible to 0.001% grade. The instrument shall be a factory-built, quality-controlled, precision instrument capable of controlling grade to a tolerance of $\pm$ 0.01%.

The laser for the grade instrument shall be provided with a collimating lens system capable of producing a spot no larger than 19 mm in a working range of 0-150 m. The intensity of the beam shall not exceed 5.0 mW.

Alignment of the grade instrument shall be controlled by either a sighting scope internal to the laser head and aligned to the beam or a transit placed on line such that the line is set into the laser by referencing the transit or laser head to the forward manhole location. The grade instrument shall initially be adjusted to the proper height to shoot through the pipe by transferring the cut from the engineer's offset hub to a reference point on the grade instrument.

Trench line and grade, also grade for select bedding if required shall be controlled by observing the laser beam with reference to a mark on a handshovel or other suitable target. The laser beam may be placed either at the level of the pipe or above the ground. If placement is at pipe level, each section of pipe shall be placed to line and grade by inserting a pipe target into each pipe and adjusting the pipe until the beam strikes the target at the proper index. If the laser is placed above ground, a story pole with an integral plumbing device shall be used to intercept the laser beam.

SUMMARY

The use of sewer lasers has become an accepted method for providing line and grade control in sewer construction. Comparing lasers to the older, more traditional methods, there are many benefits.

For the contractor, the benefits of lasers are many:

1. Marked increases in productivity
   - generally in area of 20%-30%, depending on conditions
   - no longer has to set batter boards or string lines
   - each section of pipe goes in faster
     - usually the bedding is correct the first time
     - only a few seconds are required to check the alignment; traditional methods require several minutes
   - excavated materials can be deposited on both sides of the trench
   - backfilling can be carried out as soon as the pipe is set since there are no batter boards or string lines in the way.

2. Substantial cost savings
   - increased productivity leads to 20%-30% decrease in costs
   - less labour is required
     - typically one less man per sewer crew
   - save on materials
     - not as much chance of over-excavating and having to put too much costly fill in place
     - right amount of bedding can be put in and leveled, the first time.

3. Better utilization of manpower
   - foreman no longer has to help with every section of pipe
   - now he can spend more time on what he should be doing - planning and managing the job.

4. A better, more accurate job
   - use of lasers allows greater accuracy to be attained more easily
   - less costly rework is necessary.

For the Inspector, the laser also offers benefits:

1. A better, more accurate job
   - Inspector's job is to ensure just that
   - the finished pipe forms a straight "rifle bore" and a "full moon" can be seen.

2. Less conflict with the contractor to get him to do a good job.

3. Easier to maintain control of job.

SUBJECT:

CONSTRUCTION OF SEWERS WATERMAINS AND ASSOCIATED FACILITIES

TOPIC: 9

EXCAVATION AND BACKFILL

OBJECTIVES:

The trainee will be able to:

1. Recognize various soil conditions and request appropriate modifications in excavation methods as may be necessary for the safe and efficient conduct of the work.

2. Recognize and obtain appropriate compaction densities in backfill materials.

EXCAVATION AND BACKFILL

This section deals with the techniques of excavation of a trench for the purposes of installing a sewer or watermain, as well as the backfill of the same trench after the pipe has been installed.

Pre-Excavation

Before commencing any excavation it is necessary for the inspector to be informed of reasons for the proposed work, and also of its impact on the community.

When working on existing streets it is necessary to be certain that all approvals have been obtained and that all affected parties such as local residents, police, fire and local utilities are informed.

The functional requirements of the project should also be understood, prior to excavation. Some systems are intended to be operational on a block by block basis. Some systems, such as in new subdivisions, will be totally completed prior to operation. Such conditions affect the storing of excavated material, the ordering and placing of construction material should be understood prior to commencing work.

The inspector should insure that the contractor checks for buried utilities by contacting the utility company and requesting a stake out. He should also note overhead wires, trees, etc. as well as those details shown on the plan as it is always possible that something was overlooked at the design stage or was not known. He should establish contact with local residents who may volunteer information regarding old tile drains, abandoned wells, etc.

The inspector should check basement elevations in suspected areas of tight design and look for new structures, poles, and trees which mysteriously appear between original detail survey and final construction.

He should also read the specifications pertinent to excavation and backfill thoroughly; and in addition, the soils report. Soils problems are generally predictable and the best time to request an extra pump or extra compaction equipment is before the backhoe digs the first shovelful.

The inspector should make every effort to attend the digging of test holes at the time of tendering to familiarize himself with soil conditions.

Prior to excavation, the most important thing is to check the layout in a general way. The grade sheets should be mathematically correct and the basic reference points verified.

EXCAVATING EQUIPMENT

Selection of appropriate equipment is important. Machines which are too big cause unnecessary damage to trees, poles, etc., and machines which are too small move the job too slowly, which is not only uneconomical but may also cause such problems as settlement due to frozen backfill or side-slope instability.

Bucket widths should also be checked to minimize excavation and maintain side support. Most buckets can be changed very quickly or if necessary an appropriate size can be rented.

Most trench work today is being done by hydraulic backhoes. These provide excellent control; they can be used in most sheathing situations as well as in "V" trench, and come in a variety of sizes.

In very wet tight-sheathed conditions some contractors prefer a clam bucket which is slow but is sometimes a last resort in a deep trench, and may be accepted.

Drag lines generally should be discouraged due to the wide area required for storage of material and considerable resultant damage. Some Contractors prefer drag-lines on wet sandy work but very poor grade control and considerable disturbance of the trench bottom invariably results in a poor job.

Cable activated pull-shovels are still used and are acceptable but are being replaced by hydraulic machines.

Rotary trenchers may be used for shallow, narrow trenches such as powerlines or water services.

Continuous bucket trenchers, capable of depths up to 3mm may be used, however delays due to boulders, unseen service pipes and other problems generally cause the contractor to select alternate equipment.

SOILS JUDGEMENT

The inspector should look on every bucket full of dirt as a step into the unknown.

Soil types, water content, slope stability, etc. are constantly changing factors, requiring modifications in method.

Firm clays and till soils below optimum moisture can usually be excavated easily and safely but require careful control during backfill.

Dry sand requires more careful observation during excavation since it can slip or run easily and yet backfilling is comparatively easy.

Dry silt behaves like clay but is not too common and wet silt is all too common and behaves in unpredictable and hazardous ways and often requires special treatment.

Most soils contain portions of sand, silt, and clay and, although it is an oversimplification it is generally true that excessive water and excessive silt are the prime cause of excavation and backfill difficulties.

Danger signals to look for arranged in order of difficulty might be as follows:

Problem	*Solution*
Free water in trench:	*Use pumps.*
Sides tend to slough in:	*Use box, plus pumps.*
Bottom tends to move:	*Use sheathing, pumps, plus special base.*

STORAGE OF EXCAVATED MATERIAL

It is important to store material so as not to directly damage trees, lawns, etc., but it is also important to judge what might happen during a rain storm or extended exposure to the elements. Many trunk sewers in river valleys are particularly vulnerable if excavated material is stored on the flood plain. A tight operation with minimum exposure is recommended.

Stored material should also be kept back from the wall of the trench to prevent sur-charging, and possible cave-ins, or subsidence cracking. This is a danger signal indicating weak trench bottom and a need for urgent action by the engineer.

EXCAVATION SHAPE

Note the safety requirements as well as the structural requirements pertaining to trench width, since these are sometimes in conflict.

Contractors tend to dig firm soils with trench walls which do not have enough slope and are too narrow and on the other hand, they dig wet silts or free-running sandy soils generally with a tendancy to be too wide.

"Four feet vertical with one to one slopes" means just what it says and variations should only be tolerated on the basis of the engineers direction.

All timber sheathing, metal boxes, air-shore, etc. must be approved by the engineer, but generally all such devices require vertical trench walls. Horizontal bracing will only work at 90^{o} and trying to brace "nearly vertical" walls has caused braces to slip or jacks to jump with fatal consequences.

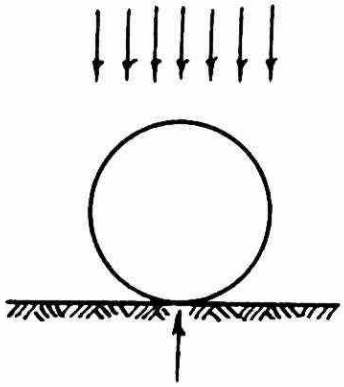
Generally, all buried conduits are installed in either "embankment" or "trench" conditions. Embankment conditions generally deliver a greater load to the conduit than is the case in trench conditions. This is because the trench sides through friction help in supporting the backfill.

At the point where a trench becomes so wide that the load no longer increases with width the trench is described as having reached the "transition width". *This width is measured at the top of the pipe*.

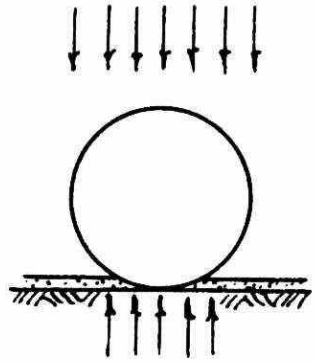
Theoretically a different transition width may be calculated for every pipe diameter, for every soil type and for every height of backfill. The inspector is cautioned against any over-simplification of this concept and it is worth noting that the Concrete Pipe Design Manual lists transition width for all pipes from 150 mm diameter to 3600 mm diameter requiring 120 charts in the process.

The essential fact to remember regarding trench width is that the load increases with width up to a maximum. If the designer has selected a pipe strength on the basis of an assumed maximum width, it is essential that this width be obtained.

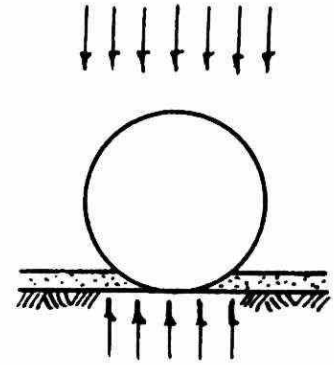
It is also essential that the bedding class be as specified. However, this is more thoroughly covered in the topic "Pipe Installation".



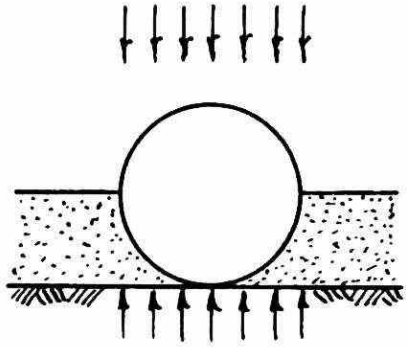
Pipe set on flat foundation without bedding results in high load concentration at the bottom of the pipe.



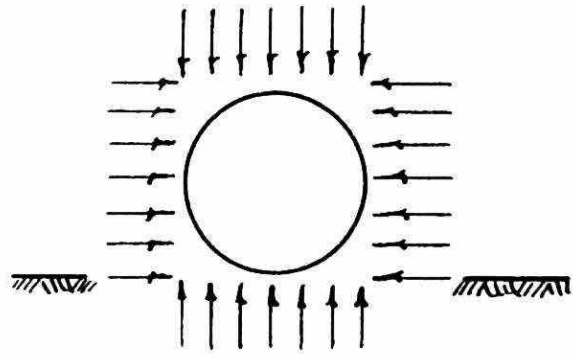
Bedding pipe over 50% of dia. results in 36% increase in supporting strength.



Bedding pipe over 60% of dia. results in 73% increase in supporting strength.



Bedding pipe over 100% of dia. results in 114% increase in supporting strength.

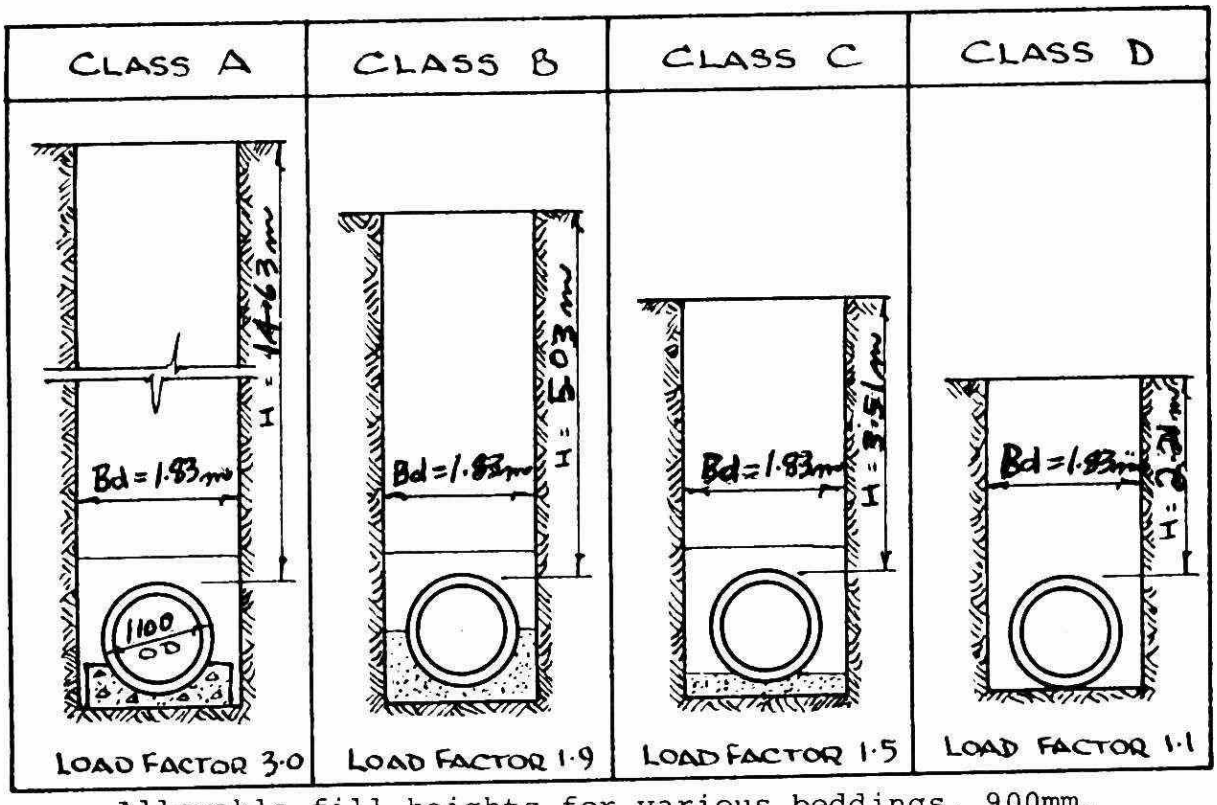


Bedding pipe over 100% of dia. and good sidefill compaction results in 150% increase in supporting strength.

CORRELATION OF BEDDING AND SUPPORTING STRENGTH

Courtesy OCPA

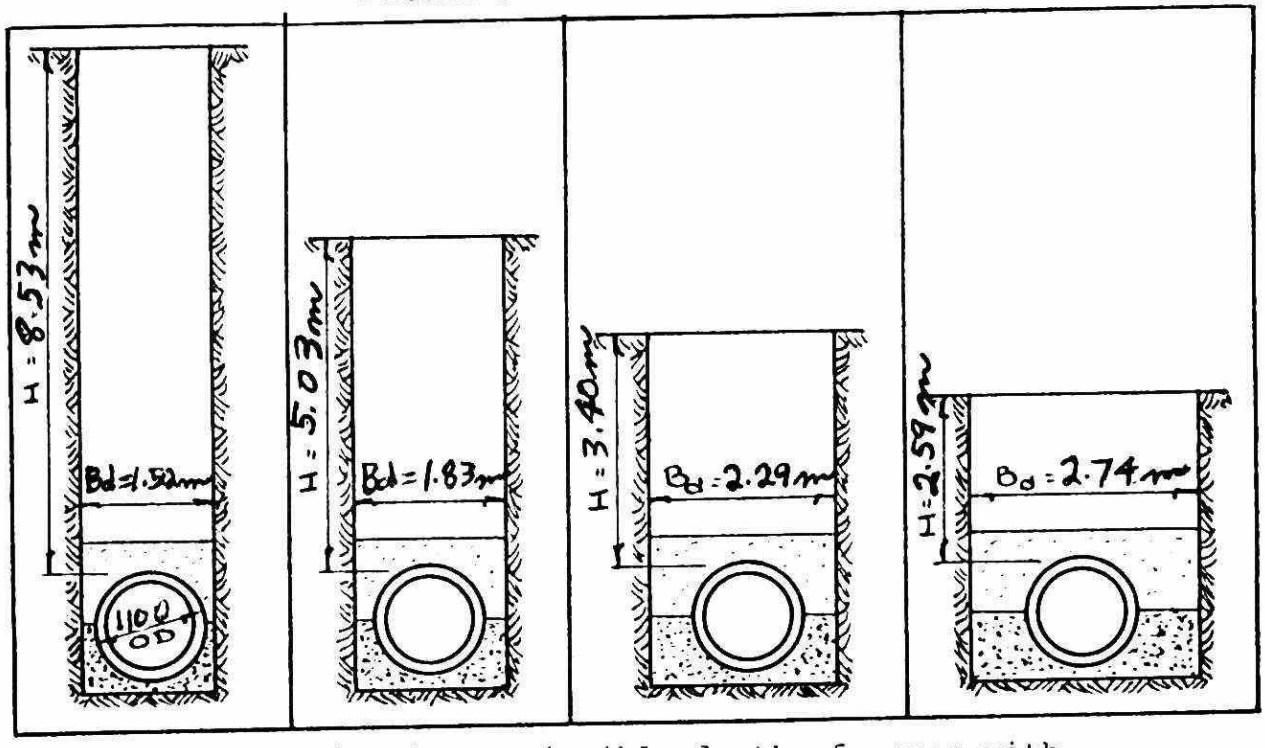
FIGURE 9-1



Allowable fill heights for various beddings, 900mm. Dia. CSA A257.2 Class III Trench Installation W= 192kg/m^3 K= 0.33 = 0.50

(OCPA)

FIGURE 9-2



Variation in permissible depth of cover with increase in width of trench 900mm dia. CSA A257.2 Class III using B bedding W= 1920kg/m^3 K=0.33 =0.50

(OCPA)

FIGURE 9-3

To emphasize these comparisons we refer you to the diagrams identified as Figures 9-1, 9-2 and 9-3.

BACKFILL EQUIPMENT

The important consideration in backfilling is to achieve a balanced operation. A small bulldozer or loader feeding a self-propelled vibratory roller is often a good combination. Trying to utilize a machine for backfilling which also doubles as a crane for lowering pipe or for drawing stone or whatever, is a mistake. Backfilling to meet a specified density is the most important part of the work in terms of extra cost to the Contractor if it is not done well.

The inspector should insist on the backfilling being done gently, in layers of a depth within the easy capability of the compactor.

Layers may be sloped, provided the compactor can work on the slope.

It may also be necessary when compacting in sheathed trenches to withdraw the timbers in stages equivalent to the layers of earth being placed. Settlements in such trenches are particularly serious because compaction is difficult and the material tends to bridge to the vertical walls but ultimately a settlement does occur. This usually happens after the Contractor's guarantee has expired, leaving the engineer and his inspector in a vulnerable position.

Types of compacting equipment are many and varied but the following summary of appropriate applications may be useful.

1. Irregular Drum Tampers - clays, tills, silts.

2. Hand Controlled Plate Tampers - sands in shallow lifts.
3. Boom-Mounted Plate Tampers - clays or sands in deep, narrow trenches which preclude the operator's entry into the trench.

Generally speaking all of the above equipment is available in vibratory or static models. A Vibratory type is usually preferable when the moisture content is less than the optimum percentage determined from a "Proctor" test. Static machines usually require more passes, but in over-optimum conditions they may be the only practical alternative which will not get stuck.

BACKFILL PROBLEMS

If the Contractor has the best equipment and the best intentions he may still not achieve acceptable results.

Material which is too wet or above optimum moisture presents a much more difficult situation. One approach is to note the "in-situ" density of the wet soil and then try to compact to this density. Another is to insist on a total compactive effort to the extent that no visible voids are present and this may produce tolerable results. However, as soon as moisture content exceeds optimum by more than about 3% it is essential that the inspector have the engineer's approval for whatever concessions may be given. *Never act alone*.

Frozen ground is also a major problem and if large frozen lumps are included in the backfill it is an absolute certainty that settlement will occur.

Special problem areas also exist near manholes or valve chambers or other obstacles in the ground. Using granular backfill in these areas is one answer but this also requires compaction.

The use of fragmented rock as backfill should be discouraged. However, where no other material is available it is essential to mix sand, gravel, or crushed rock with the rock to fill all voids. It is also essential to create a layer of fine material over the pipe to prevent damage.

Backfilling peat bogs or other very light soils presents a very special condition. It can be shown that the weight of the pipe is less than the material displaced and, theoretically it should not settle. However, it is necessary to ensure that the weight of the soil being used as backfill does not exceed the weight of the soil removed as settlement may be induced due to compression of the underlying undisturbed peat.

Approaching the Surface

The backfill should not be "topped-off" in the expectation of settlement to make room for specified road base or topsoil thickness.

It is not only neater and cleaner to restore as the job continues, but it also imposes an obligation on the Contractor to obtain good compaction to avoid making up settlements with costly surfacing materials.

SUBJECT:

CONSTRUCTION OF SEWERS
WATERMAINS AND
ASSOCIATED FACILITIES

TOPIC: 10

PIPE INSTALLATION

OBJECTIVES:

Trainee will be able to:

1. Understand proper methods and procedures for handling, storing, bedding and jointing of pipes.

PIPE INSTALLATION

GENERAL

This topic covers the handling, storage, jointing and bedding of pipe for gravity and pressure pipe lines on municipal-type projects.

HANDLING

The first thing that happens to pipe when it is delivered to a construction site is it is unloaded. However, before the pipe is unloaded it should be checked to see if it is the proper size, class and that it is undamaged (i.e. no chips, cracks, etc.). If the pipe is satisfactory it can then be unloaded. In general it is best to use mechanical means to unload pipe as this protects it from damage. Care should be taken to prevent abuse and damage of the pipe no matter what method of unloading is used since damage unnoticed can result in having to re-lay part of the pipe line due to failure found only after installation (e.g. failure to pass leakage test).

The following are some suggested methods and things to watch out for when unloading pipe on the job.

Concrete Pipe

- "Tailgate" smaller pipe sizes.
- Use a crane on the larger diameters.

Asbestos Cement Pipe

Pressure pipe larger than 300 mm I.D. and gravity pipe larger than 450 mm I.D., should be unloaded by equipment. If using ropes and skids lower one pipe at a time making sure it does not roll free during any part of its travel.

Ductile Iron Pipe

Unload using equipment, make sure you don't knock mortar lining (if any) loose.

Polyvinyl Chloride Pipe

Avoid severe impact, in particular at temperatures below - 10° C.

Avoid undue abrasion, don't slide over truck bed. When using slings they should be rope or webbing not steel or chain.

Vitrified Clay Pipe

Usually shipped in "Cryovac" packed skid loads. Use mechanical means to unload, handle pipe carefully to avoid damage.

STORAGE

If pipes are to be distributed along the trench keep the following in mind:

1. Lay or place pipe as near the trench as possible to avoid excess handling later.

2. If trench is open it is advisable to string pipe on the side away from excavated earth wherever possible so that pipe can be moved easily to the edge of trench for lowering into position.

3. If trench is not yet open find out to which side excavated earth will be thrown, then string out on the opposite side (leave room for excavator).

4. Place pipe so as to protect it from traffic and heavy equipment; also, safeguard it from the effects of any blasting that may be done.

5. Care should be taken that pipe do not roll into the trench.

However, if the pipe are to be stockpiled the following should be remembered.

1. Stockpiles should be built up on a flat base.

2. The bottom layer should be supported uniformly along the barrel of the pipe so that the bells do not touch the ground.

3. When stacking pipe, bells should project over the end of the barrels in alternate layers.

4. Keep various sizes and classes grouped. Put short lengths, fittings, adapters, etc. in separate piles where they will be readily available.

5. When stacking PVC pipe do not stack loose pipe over one metre high and protect from sunlight by covering with a tarpaulin or other opaque material. Be sure to allow for the circulation of air beneath the cover.

6. Pipe should be stacked in a manner so that it will not roll down a grade.

Gasket Storage

Store all rubber gaskets and lubricant at a central point and distribute as needed. Keep them clean, away from

oil, grease, excessive heat and electric motors which produce ozone. The best way is to leave them in their original cartons and stored in a cool, dry place.

JOINTING

General

The main objective when jointing a pipe is to obtain a watertight seal. This is true of both pressure and gravity-flow lines. In this section we will deal mainly with flexible joints for the most commonly used types of pipe.

Concrete Sewer Pipe

Basically, a bell and spigot design with a rubber gasket compressed between the bell and spigot. See Figure 10-I for various joint types and methods of installation.

Vitrified Clay Sewer Pipe

There are three different types of flexible joints for vitrified clay pipe used on Ministry of the Environment Projects. They are:

1. "Advanced Design Flex Lox"
2. "Flex Lox II"
3. "Kwik-Seal"

The "Advanced Design Flex-Lox" joint consists of a smooth resilient polyurethane gasket cast on and firmly affixed to both spigot ends of a plain end vitrified clay pipe and a separate external rigid sleeve made of PVC for joining the pipe together. The pre-formed resilient spigot components and the internal contour of the PVC rigid sleeve are designed to form a compressed mating surface when the

pipe is telescopically assembled. See figure 10-2 for methods of joint assembly.

The "Flex Lox II" joint consists of a rubber "O-ring" placed in a groove machined in one end of a pipe with a glass fibre reinforced sleeve firmly affixed to the other end of the pipe. The O-ring and the interior of the sleeve form a compressed mating surface when the pipe are telescopically assembled. The method of joint assembly is as follows:

1. Clean the joint surfaces.
2. Install the O-ring in the groove on the spigot.
3. Equalize stretch in the O-ring.
4. Lubricate the outside of the O-ring and the inside of the sleeve (bell).
5. Push the spigot end home.

The "Kwik-Seal" joint consists of a separate external coupling in which two rubber gaskets are imbedded. The spigots of plain end pipe are pushed into the coupling forming a watertight seal. The method of joint assembly is as follows:

1. Clean the ends of the pipe and the coupling.
2. Lubricate about 50 mm of the end of the pipe to be joined.
3. Place coupling on firm base and press lubricated pipe end into coupling as far as the stop.
4. Lay the first pipe with coupling facing next pipe.
5. Apply coupling on next pipe in the prescribed manner.
6. Lubricate bare end and home into previously laid pipe.

Asbestos Cement Sewer and Pressure Pipe

The joints are basically friction-type couplings using a rubber gasket compressed between the spigot of the pipe and a recessed ring on the inner wall of the coupling.

The method of assembly of the joint is as follows:

1. Clean the groove in the coupling.
2. Install the rubber gasket in the groove.
3. Lubricate the nose and taper portion of the spigot back to the stop shoulder.
4. Push the joint home.

Ductile Iron Pipe

The most common flexible joint is the "Tyton" joint. This consists of a rubber gasket compressed between the bell and the spigot of the pipe. The method of joint assembly is as follows:

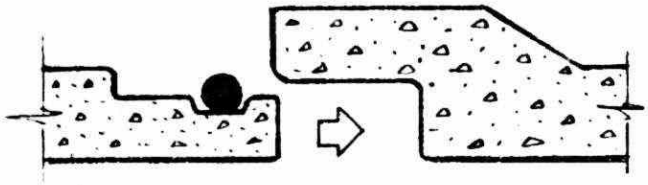
1. Clean the gasket groove in the bell.
2. Install the rubber gasket.
3. Lubricate the gasket.
4. Push home the spigot end until the reference mark is reached.

Mechanical joints are also available.

Polyvinyl Chloride Sewer and Pressure Pipe

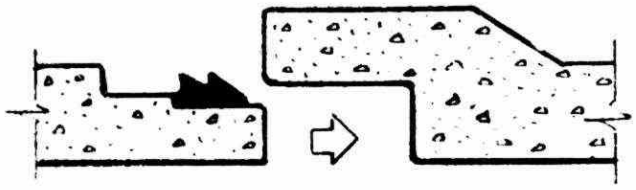
The joint used on PVC pipe is usually similar to the "Tyton" joint used on ductile iron pipe. The only installation difference is that rather than lubricating the rubber gasket the spigot of the pipe is lubricated before homing the pipe to the reference mark.

TYPICAL JOINT DESIGNS



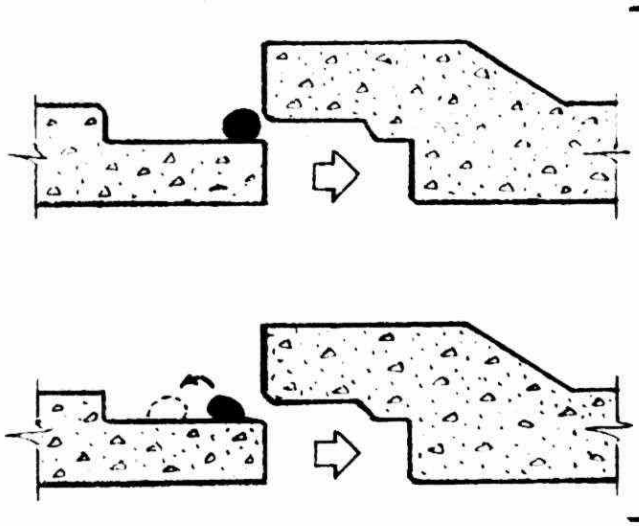
RECESSED

CLEAN JOINT SURFACES, LUBRICATE INSIDE OF BELL, LUBRICATE "O" RING, EQUALIZE TENSION.



SINGLE OFFSET

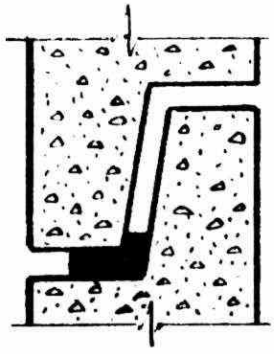
CLEAN JOINT SURFACES. POSITION GASKET ON SPIGOT & EQUALIZE TENSION. APPLY LUBRICANT ON TOP OF GASKET & INSIDE OF BELL.



ROLL ON

CLEAN JOINT SURFACES. POSITION GASKET AT END OF SPIGOT.
DO NOT LUBRICATE

JOINT OPENING — FOR PIPE UP TO & INC. 1350 mm — 13 mm MAX.
FOR PIPE 1500 mm & LARGER — 19 mm MAX.



MANHOLE

CLEAN JOINT SURFACES
NO LUBRICANT REQUIRED

OCPA

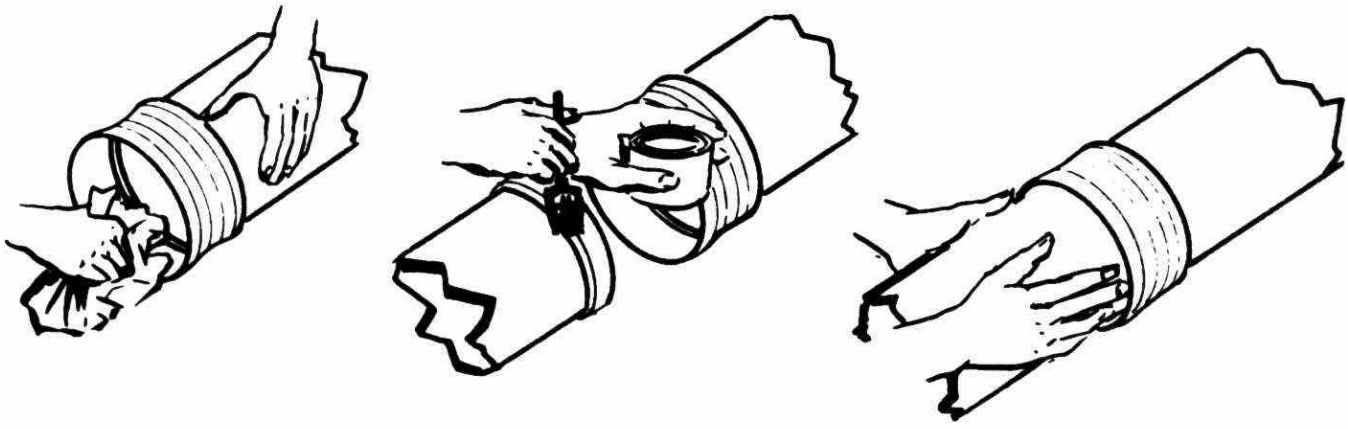
Figure 10-1

INSTALLATION INSTRUCTIONS

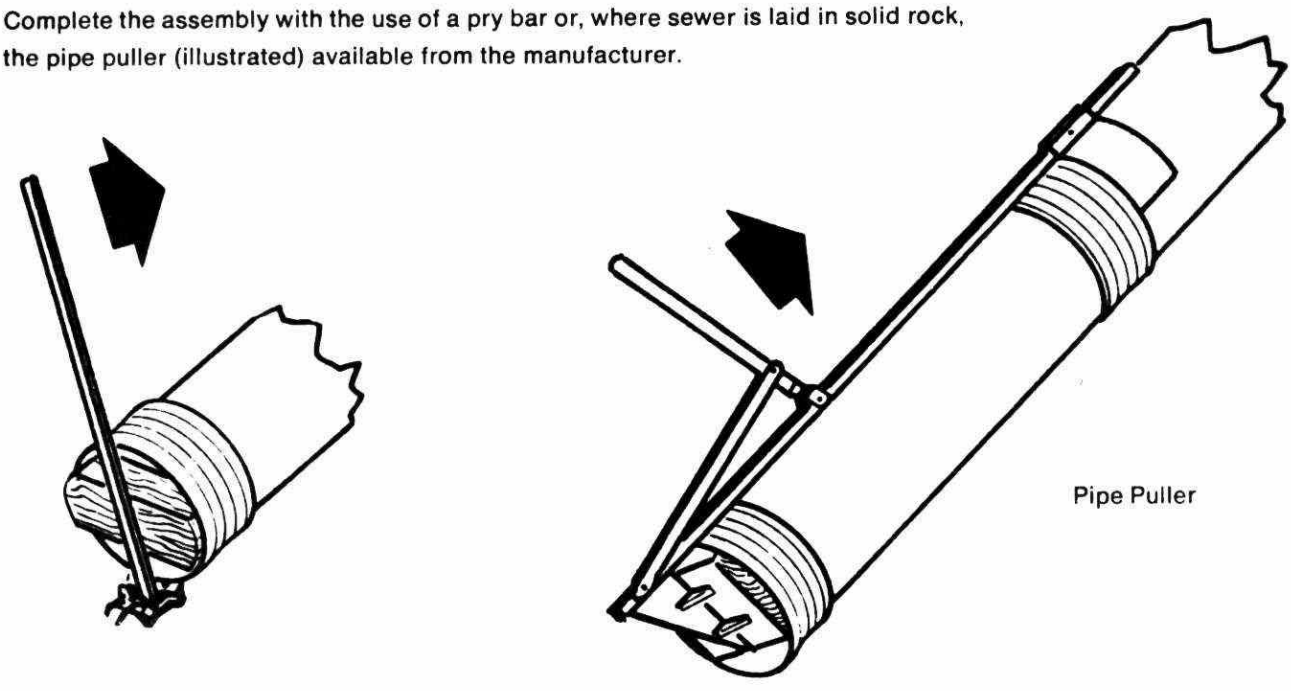
① Wipe the PVC collar and spigot clean

② Lubricate spigot

③ Insert spigot firmly into PVC collar



④ Complete the assembly with the use of a pry bar or, where sewer is laid in solid rock, the pipe puller (illustrated) available from the manufacturer.



Pipe Puller

When using a pry bar it is necessary to use the Flex-Blok or similar timber fulcrum.

NEW "FLEX LOX" VITRIFIED CLAY SEWER PIPE

National Sewer Pipe Ltd.

Figure 10-2

Principal Considerations for Jointing

1. Always clean the joints and gaskets prior to jointing.

2. Keep the pipe horizontal when jointing (use slings or cranes).

3. Use a bar or come-along when homing pipe. Never use the bucket of a backhoe as it may break the pipe.

4. Apply lubricant evenly to gaskets and pipe (where applicable).

5. When using a trench box anchor pipe so they will not move when the box is pulled ahead.

6. Obtain manufacturer's jointing instructions and follow them.

BEDDING

General

The purpose of bedding a pipe is two-fold; 1) to provide firm continuous support for the pipe to maintain the grade set for the pipe line;and 2) to provide the soil side support for the pipe to enable the pipe and the soil to work together to meet the design load requirements.

If a pipe is set on a flat foundation without any bedding there is a high load concentration at the bottom of the pipe. If the pipe is bedded over 50% of the diameter of the pipe, the pipe can support 36% more weight than it could without any bedding. Increase the bedding to 60% of the diameter the pipe can now support73% more weight than with no bedding. Extend the bedding to 100% of the pipe diameter and the pipe will now support 114% more weight than the

original unbedded pipe. Add good side fill compaction to bedding under 100% of the pipe diameter and you now have 150% of the load-carrying capacity that you had when you started with an unsupported pipe.

Classes of Bedding

There are four classes of bedding commonly used - classes A, B, C and D. The best class of bedding (Class A) enables a given pipe to carry a load three times as much as that load the pipe could carry in a three-edge bearing test. The worst class of bedding (Class D) enables the pipe to carry little more than it would in the three-edge bearing test. This ability of a bedding to increase the load-carrying capacity of a pipe over its load-bearing capacity in the three-edge bearing test is measured by a term called the load factor. If a certain bedding allows a given pipe to carry twice as much load as it can carry in the three-edge bearing test, the load factor is 2.0. Similarly, if a bedding allows a pipe to carry 3.0, 1.5 or 1.1 times as much load as that pipe in the three-edge bearing test then that bedding would have a load factor of 3.0, 1.5, or 1.1 respectively.

Class 'A' Bedding

Generally specified as a concrete cradle under the pipe extending approximately half way to spring line. Its load factor is 3.0.

Class 'B' Bedding

Generally specified as a well compacted granular cradle extending out to the walls of the trench and up to the spring line of the pipe. Its load factor is 1.9.

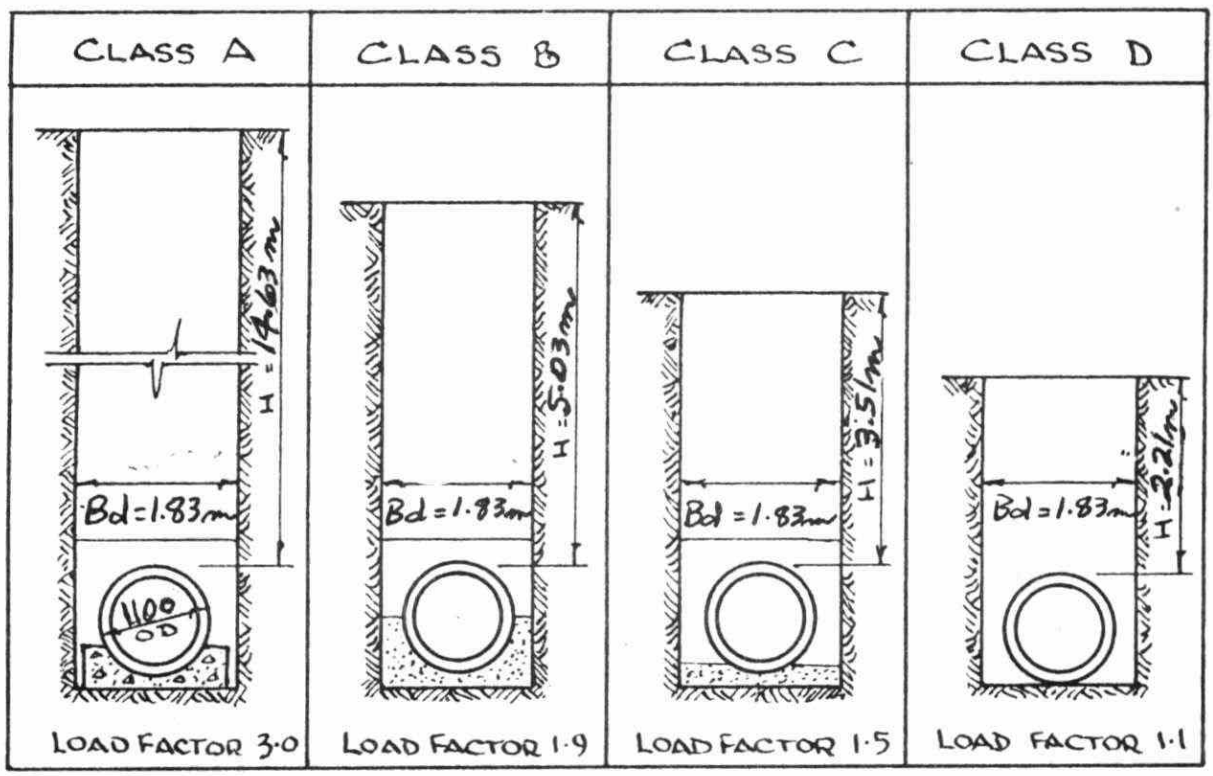
Class 'C' Bedding

Generally specified as shaping the bottom of the trench to receive the pipe. Its load factor is 1.5.

Class 'D' Bedding

Basically burying the pipe with no preparation of the trench bottom. Its load factor is 1.1.

The following figure illustrates the effect of the various bedding types upon the depth of cover over a pipe with the only variable the bedding type.



Allowable fill heights for various beddings, 900mm. Dia. CSA A257.2 Class III Trench Installation
$W=1920kg/m^3$ K=0.33 =0.50

OCPA

FIGURE 10-3

Bedding Procedure

The primary requirement when bedding a pipe is to have a stable and uniform foundation. It should be smooth and free from large stones, rock, boulders, construction material debris, large clods of earth and frozen material.

A 75 to 150 mm layer of bedding material is usually spread on the original trench bottom in order to bring the bedding up to grade for laying the pipe. The pipe barrel must be given even continuous bearing for its full length. There should be no high or low spots on the bottom of the trench nor should couplings or bells rest on the ground. The above cause point loads which can result in breaks in the pipe. The high and low points can be avoided by levelling the trench bottom and digging holes under the bells or couplings if necessary.

Once the trench bottom has been shaped properly and the bell holes dug it is necessary to compact the material under the haunches of the pipe. This is a critical part of the operation. Usually this is done with hand tampers. In large diameter pipe it is usually best to shape the trench bottom to fit the O.D. of the pipe. After the material under the haunches of the pipe has been installed satisfactorily, bring the rest of the bedding up to the required height in shallow lifts that are properly mechanically compacted.

Bedding Material

The best bedding material is a well graded granular material up to 19 mm in size free from lumps and frozen material. In rock trenches it is best to use a 19 mm clear stone so that the bedding material cannot wash away down fissures in the rock which could happen with a bedding material containing fines. Also, clear stone is recommended in wet conditions.

Principal Considerations for Bedding

1. Use 19mm maximum size granular material.

2. When bedding plastic pipe, it is paramount that the bedding material is properly compacted out to the trench walls since a flexible pipe uses the strength of surrounding earth to help carry the load.
3. When installing concrete cradle (Class 'A' bedding) in a rock cut make sure there is a space between the walls of the trench and the concrete.

4. Don't use fine bedding material in a trench cut through rock.

SUBJECT:

CONSTRUCTION OF SEWERS
WATERMAINS AND
ASSOCIATED FACILITIES

TOPIC: 11

Leakage and Pressure
Testing of Gravity Sewers,
Sewage Forcemains, and
Watermains

OBJECTIVES:

Trainee will be able to:-

1. Perform infiltration and exfiltration tests on sewers.

2. Perform pressure and leakage tests on watermains and sewage forcemains.

3. Recall the procedure and the safety requirements for the Low-pressure Air Test.

4. Recall some methods of leak detection.

LEAKAGE AND PRESSURE TESTING

OF

GRAVITY SEWERS, SEWAGE FORCEMAINS AND WATERMAINS

LEAKAGE TESTING OF SEWERS

GENERAL

Sewers are tested for leakage both in and out of the pipeline. Leakage into a system is known as infiltration and leakage out of a system is known as exfiltration.

Infiltration of ground water into a sewage system is undesirable because:-

1. It reduces the hydraulic capacity of the pipe to carry wastewater.

2. It overloads the treatment facility resulting in either insufficient treatment or requiring capital replacement.

3. It allows roots to enter the system which cause blockages.

4. It washes fine material from the bedding into the pipe resulting either in structural failure of the pipe or collapse of the ground above due to settlement.

Infiltration results in increased cost because it is found in the fact that it is often necessary to expand either the collection or the treatment system much earlier than was planned.

Exfiltration from a sanitary sewage system is undesirable for two reasons. Sewage flows must maintain a minimum velocity of 0.6 m/sec in order to prevent the solids from settling out and eventually blocking the sewer. It is therefore undesirable to lose the transporting medium (i.e. water by leakage). The other factor is of course that the leakage may eventually pollute the ground water table in that area.

Inspectors cannot watch construction crews every minute to ensure good work. Even if they could, damage may occur during the backfill and compaction of the pipeline. Since every pipeline, no matter how well laid, leaks (due to joints, pipe wall porosity, etc.), standards of acceptable infiltration and exfiltration have been set down by the Ministry of the Environment. The standard for leakage due to infiltration is that the leakage shall not exceed 0.15 L per mm internal diameter of pipe per 100 m of pipe per hour. The leakage standard for exfiltration is 25% higher than the above.

Example: The distance from one manhole to the next manhole is 100 m, the internal diameter of the sewer is 250 mm. The allowable infiltration is therefore:

$.15 \times 250 \times 1 = 37.5$ L/hr.

or

$37.5 \times 24 = 900$ L/day.

The allowable exfiltration for the above stretch of sewer is equal to:

$250 \times .15 \times 1.25 \times 1 = 46.9$ L/hr.

$46.9 \times 24 = 1125$ L/day.

Infiltration Test (Figure 11-1)

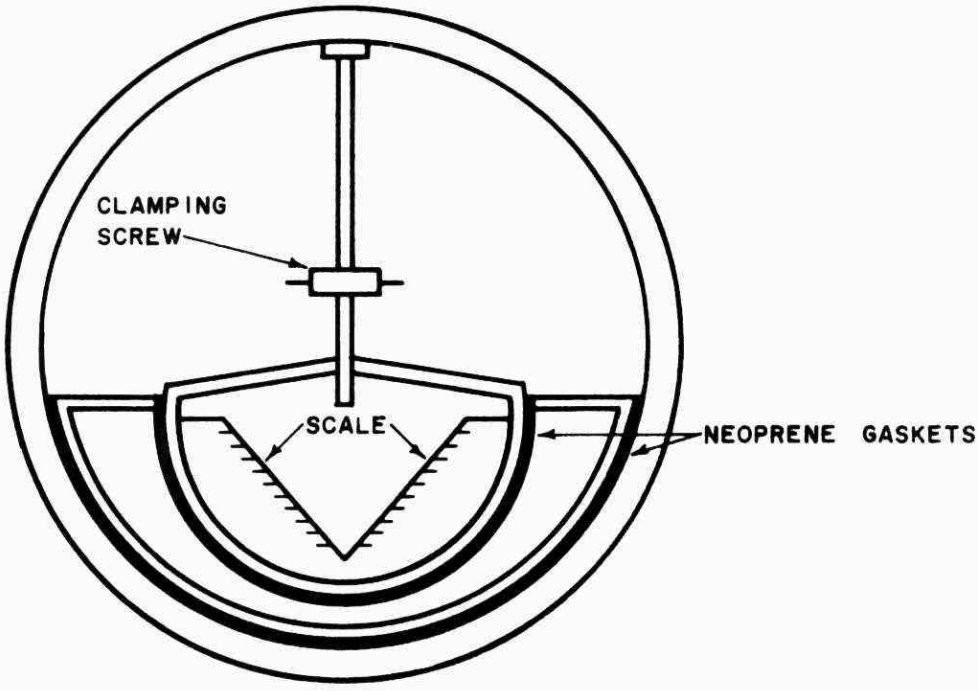
Every section of sewer where the ground water table is two feet or more above the crown of the highest pipe in the section is to be tested for infiltration. The testing procedure is as follows:

1. Block off the upstream manhole with a pipe plug.

2. Using a V-notch weir; install weir in lower end of section to be tested and allow water to flow over the weir until the flow is steady, without fluctuations. Read the flow from the weir (usually weirs are graduated in litres per day). Record the flow reading, as well as the date, sewer diameter, distance from manhole to manhole, manhole numbers and the approximate height of ground water above the crown of the highest pipe.

3. An alternate to the use of the weir is to block the exit from the lower manhole and allow the water to build up in that manhole. Pump the water periodically into containers of known volume. This method should be done over a much longer period of time since it is somewhat more inaccurate.

4. Calculate leakage and compare to allowable leakage based on 0.15 L per mm of internal diameter of pipe per hundred metres of pipe per hour. Service connections from the mainline sewer to the property line must be included in the calculation of the allowable leakage.



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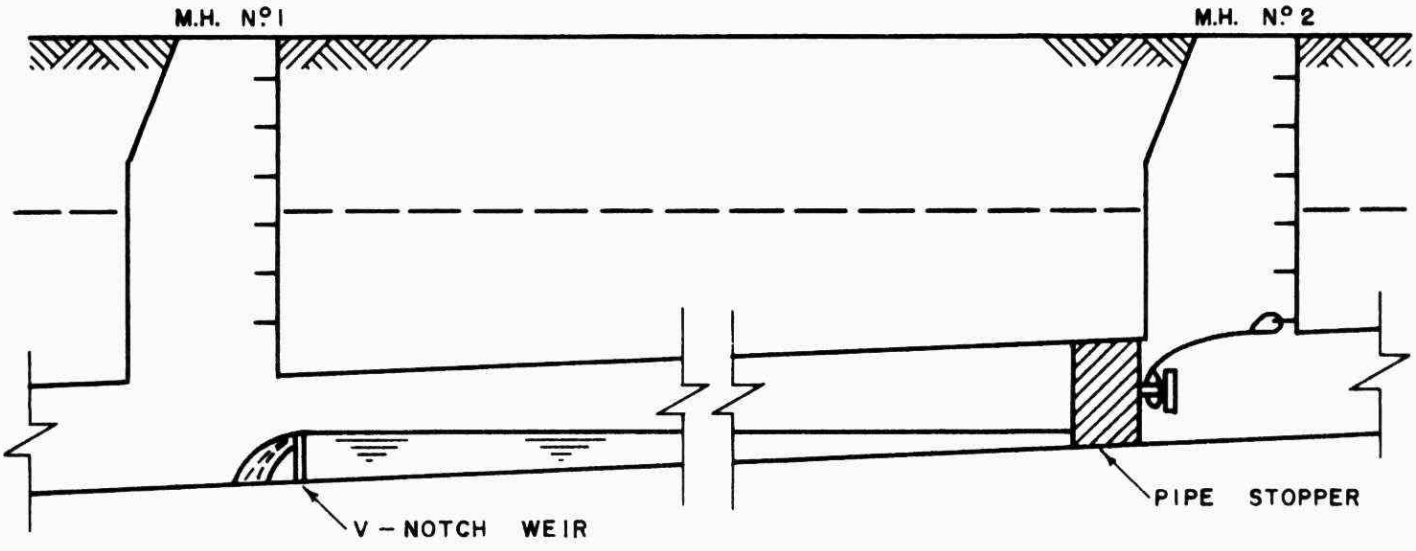


INFILTRATION TEST

Figure 11-1

Exfiltration Test (Figure 11-2)

In testing for exfiltration, the minimum net internal head on the section of sewer being tested shall be 0.6m measured from the highest point of the highest service connection in the said section, provided that the maximum net internal head on the line is not greater than 8m. In calculating the net internal head, allowance should be made for the applicable ground water head, if any. The method of testing is as follows:

1. Install a plug at the lower end of the test section.

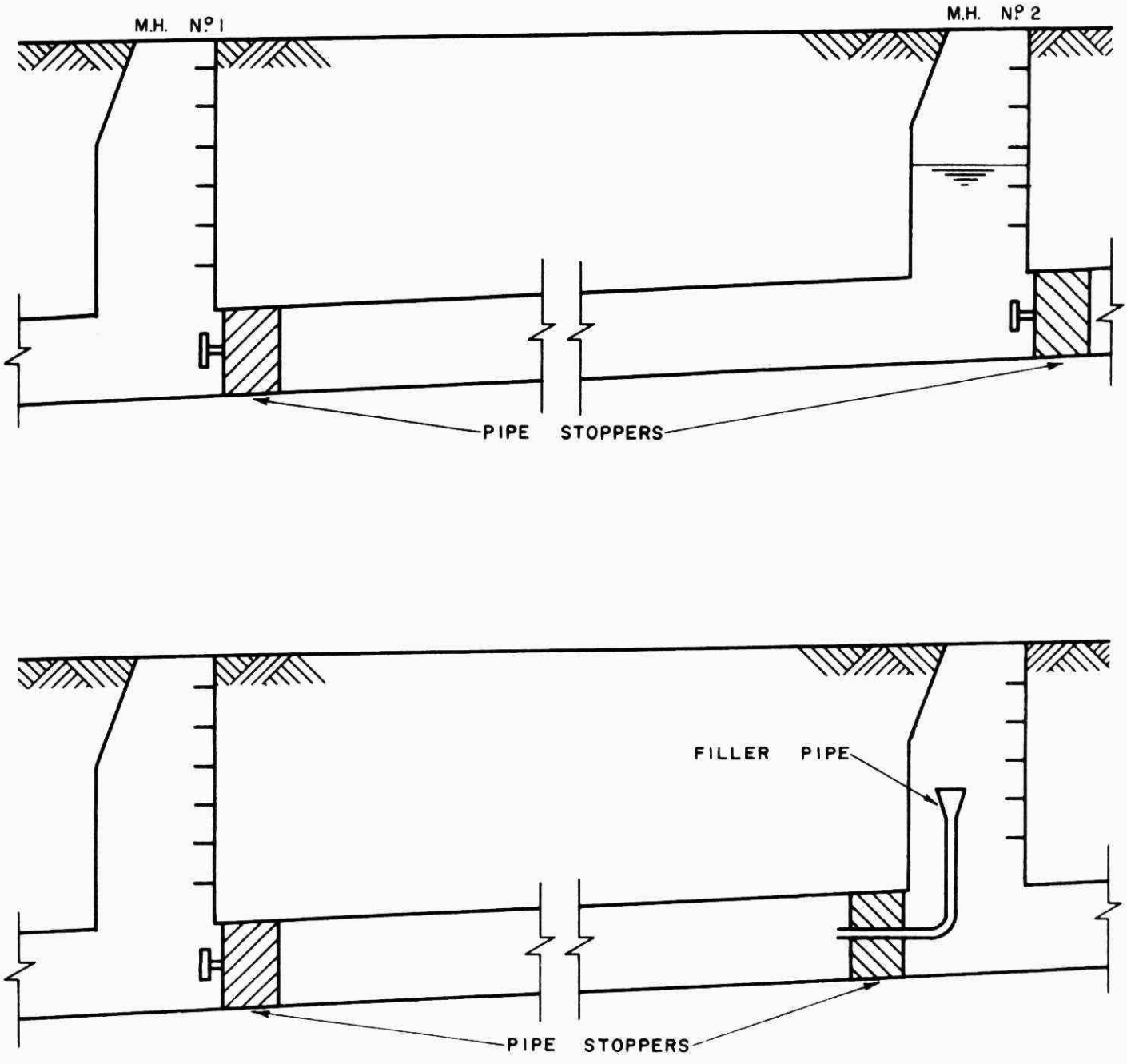
2. Plug the incoming pipe(s) at the upper manhole.

3. Fill the section with water at the upper manhole to a level 0.6m above the highest pipe in the section being tested. Do not exceed a net internal head of 8m. Do the filling slowly so that air can escape.

4. Allow the pipe and manhole walls to saturate with water for several hours, then fill to the level required in Step 3. Measure the distance from the water level to the top of the manhole frame.

5. Let stand for one hour and then re-measure the depth of water from the top of the manhole frame to the surface of the water. Therefore, this is the exfiltration in the section including the upper manhole.

6. Calculate the amount of exfiltration by means of volumes and compare it to the allowable exfiltration.



EXFILTRATION TEST

Figure 11-2

7. Record the amount of exfiltration and other pertinent data as in Step 2 for Infiltration.

8. The allowable exfiltration is 25% greater than for infiltration. In calculating the allowable exfiltration, include all service connections and an allowance of 3.0 litres per hour per metre of head above the invert of the manhole for each manhole included in a test section.

General Notes For Testing

1. Sewers should be tested immediately after completion.

2. Testing must be done before the private portions of the service connections to the houses are installed.

3. Ensure that installed risers are properly plugged so that no leakage can occur there.

4. When testing for exfiltration ensure that the total head at the lower manhole does not exceed 8 m.

5. Exfiltration testing is used whenever there is less than 0.6 m of external head on the highest pipe in the section to be tested. In all other cases, an infiltration test is used.

Low Pressure Air Testing

An alternative to the above two methods of test is low pressure air testing. Low pressure air testing is best used where testing by water is difficult due to water not being readily available or because of freezing problems.

It can be also used in lieu of exfiltration testing when the net external head on a system exceeds 8m. However, there is no accepted data relating actual leakage allowances to air pressure testing.

Test Procedure (Figure 11-3)

The low pressure air test is a test which determines the rate at which air under pressure leaves an isolated section of a pipeline. This rate indicates the presence or absence of leaks. The test procedure follows:

1. Isolate Pipe to be Tested

   The section of pipe between two manholes to be tested is plugged at each end. Plug the ends of all branches, laterals and wyes which are included in the test section. All plugs should be carefully braced to prevent slippage and blow-out due to internal pressure. One of the plugs provided must have an inlet tap or other provision for connecting an air hose.

2. Connect Equipment

   Connect one end of an air hose to the plug used for the air inlet. Connect the other end of the hose to the portable air-control equipment. This equipment consists of valves and pressure gauges needed to control the rate at which the air flows into the test section as well as providing a means of monitoring the air pressure inside the pipe. Connect an air hose to a source of compressed air and the control equipment.

Figure 11-3
Low Pressure Air Test

3. Add Air

Supply air to the test pipe section. Monitor the air pressure so that the pressure inside the pipe does not exceed 34.5kPa.

4. Stabilize

When the pressure reaches 24.1kPa, throttle the air supply so that the internal pressure is maintained between 20.7 and 24.1kPa for at least 5 minutes. This 5 minute period allows time for the temperature of the air to come to equilibrium with the temperature of the pipe walls. During this time, check all of the accessible plugs with soap solution to detect any possible leakages. If any plugs are found to leak, bleed off the air, tighten the plugs, and begin again.

5. Determine Rate of Air Loss

This step can be performed in two ways -

a) Flowmeter method - this procedure is used when the rate of air loss is high (greater than 4.7L/sec.). The control equipment includes rotameters or other air flow measuring devices. Air is supplied to the pipe section at such a rate that the internal pressure is maintained at 20.7kPa. The flow rate is read in L/sec. The pressure of the metered air is read. The rate of air flow is corrected for pressure and temperature and is recorded in L/sec. of air under standard conditions of pressure and temperature. (Standard pressure is 101.3kPa, standard temperature is 20° C.

b) Stop-Watch Method

This procedure is used for the testing of newly constructed pipe lines where air losses are usually small. The control equipment consists of pressure gauges, valves and a pocket stop watch. After the temperature has been allowed to stabilize for the five-minute period, the air supply is disconnected, and the pressure is allowed to decrease to 20.7kPa. At 20.7kPa, the stop-watch is started to determine the time required for the pressure to drop to 17.2kPa.

The time required for a loss of 3.5kPa, at an average pressure of 20.7kPa can be used to compute the rate of air loss. For a precise calculation of the rate of air loss, the temperature of the air inside the pipe section and the barometric pressure should be determined and recorded. However, this refinement has been found unnecessary for the usual acceptance test.

Safety Requirements

The use of air under pressure for the testing of sewers has added two new hazards which are of concern to the users of this method.

It is very important that the plugs be properly secured and that care be exercised in their removal. The total force on a 325mm plug at 0.31kPa is over 3500N. If one considers that a plug weighing 4.5kg, acted upon by this force over a distance of 0.3m, attains a velocity of nearly 22m/sec or almost 80km/hr., it is obvious that the pressure in the pipe must be completely relieved before the plug is loosened. This fact has usually precluded

the use of compressed air for the testing of larger pipes and pipelines of great length. The second hazard is the possibility of loading the sewer line with the full pressure of the compressor. It is interesting to speculate as to what would yield first if 1000 to 1400kPa pressure were imposed on a sewer line.

> *Under no circumstances should a person be allowed to be inside a manhole while the air pressure is applied to the pipeline.*

In some sets of equipment the piping is arranged so that the pressure reducer and flowmeters can be by-passed by an appropriate manipulation of the valves. If for any reason the valve is not closed at the proper time, the sewer line could be exposed to very high pressure. It is therefore advisable that all air testing apparatus be equipped with a pressure relief device designed to blow out at 40-55kPa.

General Comments

Testing sewers by using air has been opposed in the past partly for the lack of reliable formulas, experience and partly for lack of less porous pipe materials. Since then sewer materials and construction practices have improved to the point that air testing is now practical. However, it has to be emphasized that the Contractor's representative on the site as well as the Inspector have to be thoroughly familiar with this testing method and its hazards. Air testing is not recommended for use on concrete sewer pipe.

Ground Water Adjustment

An air pressure adjustment is required when the prevailing ground water is above the sewer line being tested.

Under this condition, the air test pressure must be increased 9.8kPa for each metre of water above the invert of the pipe.

LEAK LOCATION IN NEW SEWERS

An infiltration, exfiltration or low pressure air test only indicates whether a section of sewer is satisfactory or unsatisfactory. If a section of sewer has failed the above tests, it now becomes a question of exactly locating the faults so they can be repaired to give a watertight system. There are two common methods used to locate leaks in a system, they are air-testing equipment and camera inspection.

Air testing equipment can be very effectively used for the location of leaks in a section of sewer that has failed to pass a leakage test. This is done by connecting two inflatable test plugs with a short length of cable and air hose and testing the line in short sections by pulling the connected plugs through the sewer. The plugs are inflated, pressure built up, and the test made. The plugs are then deflated and moved to the next position and the test is repeated until the leak is located. By using this method, it is possible to cover about 60m of sewer per hour and locate leaks fairly accurately. The test sections should overlap each other to prevent covering a leak with a test plug.

One drawback to the above method is that it does not identify what the problem is - a broken or crushed pipe, loose joint, poor service connection or displaced gasket. Camera inspection, using either a still or TV camera, solves this problem. In this method, a camera is pulled through the pipe from manhole to manhole by means of a previously strung through cable.

The still camera method uses an automatic 35-mm camera and electronic flash contained in a watertight casing. A power cable leads from the camera to control

equipment located on the ground surface which is used to remotely control the picture-taking. At the opposite end to the power cable is a normal wire cable used to pull the camera through the pipeline. Normally, a camera is winched forward into the pipe a desired distance (usually about 1.5m and then stopped. The Operator then trips the camera - the shutter and flash operating together by remote control. Chainages into the pipe are determined from graduations on the power cable which is trailed behind. It is possible to locate faults within 30mm by careful interpretation of the resulting photographs.

Camera inspection is also performed using a TV camera encased in a watertight casing. This method is more versatile since it is possible to see the complete sewer without missing any parts. A continuous picture of the sewer is projected onto a TV monitor, usually located inside of a specially equipped van. If an interesting feature appears, the camera can either be backed up or pulled ahead to get a close-up view. If desired, still photographs can be taken off the monitor screen for a permanent record. However, some systems employ an automatic still camera located in the same casing as the TV camera. This latter method gives better photographs for interpretation. It is also possible to record the results of the TV inspection on video tape.

Photo inspection of a system should not be substituted for some sort of leakage testing. It is not possible for TV or still inspection cameras to look up service connections and exfiltration leaks located there are missed. Nor is it practical to put a camera through a sewer service connection pipe.

Inspection cameras can also be used to evaluate the condition of sewers that are in service. From the results of the inspection it can be determined whether to re-build or rehabilitate the sewer.

ALIGNMENT CHECK OF SEWERS

Once a sewer has been built it should be checked to see whether it has been laid true to line and grade. Basically this means looking through the sewer. The downstream end of the sewer should be "backlighted" with a powerful light and one should look downstream, either directly or through the reflection in a mirror to see if the pipe is off line or grade. The normal use of inspection cameras does not tell one the elevation of the sewer between manholes. At the best, a rough indication of dips and misalignment may be obtained from depth of ponded or backed-up water.

TESTING OF WATERMAINS

Once a watermain has been thoroughly cleaned it should be tested for water-tightness. This will give an indication of the quality of workmanship and materials used in the watermain and its fittings. Normally, the main is tested for both pressure and leakage.

The normal test pressure is 1MPa, (1000 k Pa) which is well above the maximum working pressure of a water system.
However, care must be taken, when testing plastic pipe, that the pipe is not over stressed. Polyvinyl chloride (PVC) pipe must be tested to a pressure greater than the Series or Class Number (e.g. Series 1100 must not be tested to a pressure greater than 1100 k Pa). Polyethelene pipe must not be tested to a pressure greater than 1.5 times the series number.
The leakage standard irrespective of pipe type used by the Ministry of the Environment is 2.22L per day per mm of internal diameter of pipe per km of pipe.

The test method is as follows:

1. Make sure that all anchors and thrust blocking has been installed in the pipe.

2. Install a pressure pump with make-up reservois in the system to be tested. It should be installed at the end of the pipe, at a service connection or at a hydrant.

3. Start filling the test section with water.

4. Start applying pressure with the pump. Before bringing the pressure to the full test value, bleed all air out of the mains by venting through hydrants, service connections and air release valves.

5. Once the lines are full and all air has been let off, apply the full test pressure of 1MPa.

6. After the test pressure has been maintained for several hours, conduct a leakage test by measuring with the make-up reservoir the amount of water that has to be pumped into the line in order to maintain the test pressure at]MPa for one hour.

7. Measure the amount of leakage and compare it to the standard of 2.22L per day per mm of diameter per km of pipe.

8. If less than the allowable leakage has been measured the line is satisfactory.

If the line has failed the leakage test, it is necessary to find the point or points where the excessive leakage is taking place. Before rushing off to dig up the entire line, there are a few steps that can be taken to ensure that it is a pipe leak, and not a leak at a fitting. First, leave the line under normal pressure. The next day, repeat the test. If the leakage measured the next day is

greater than before, the leak probably is in a pipe joint or a damaged pipe. If the leakage is the same, it is more probably in a valve or a service connection.

To determine which it is, take the following steps. Insert the key for the curb stops in each shut-off, and listen at the top of the key. It may be possible to hear a leak since the key acts somewhat like a stethoscope. If a leak is heard, open the shut-off and close it again. If there is now no audible leak, test the section again. If no leaking curb stops are found, crack the main valves at the ends of the test section several times and close them again. This is to flush out any sand grains in the valve seats that may prevent the valves from closing completely causing slight leakages.

If it is found that the leakage does not occur at either of the above points it is then necessary to try and find a leak through trial and error. Some sort of leak detector such as a sensitive microphone with amplifier and ear phones is necessary.

Any leaks in the line should be repaired, and the line re-tested until the measured leakage is less than the allowable leakage.

TESTING OF SEWER FORCEMAINS

Sewage forcemains are subjected to both pressure and leakage testing. The method of test is the same as outlined for watermains except that a lower test pressure is used. The test pressure is usually given in the contract documents and varies depending on the pressure used in the forcemain.

SUBJECT: CONSTRUCTION OF SEWERS, WATERMAINS, AND ASSOCIATED FACILITIES

TOPIC: 12 DISINFECTION OF WATERMAINS

OBJECTIVES:

The trainee will be able to:

1. Recall the operations involved in the disinfection procedure of newly constructed watermains.

2. Identify the methods of watermain chlorination.

DISINFECTION OF WATERMAINS

GENERAL

In a public water-distribution system, all newly laid watermains, or existing watermains which have been repaired, should be disinfected before being placed into service. It is necessary to follow this practice in order to protect the consumers against the possibility of infection which could result from ingestion of water contaminated by disease producing organisms.

In all likelihood, the newly constructed system will have sustained contamination during transit, storage on the site of the components and laying of the piping. Often the pipe must be laid in soggy trenches and possibly on occasions be in contact with wastewater or even sewage admitted into the trench through service cuts.

In general, the disinfection procedure consists of four operations.

1. Cleaning
2. Chlorination
3. Final Flushing
4. Bacteriological Testing

CLEANING

To ensure successful disinfection, the pipe-line system must be mechanically cleaned. Lumps of mud, sand, dirty water or a variety of debris left in the piping during construction, if allowed to remain in the system, will

shield bacteria from contact with the chlorine solution resulting in incomplete disinfection and possibly delivery of contaminated water to the consumers. Improper cleaning of new watermains may also cause problems, such as:

1. Growth of nuisance organisms in the distribution system creating bad taste, odours or discoloured water.

2. A dirty new watermain may contaminate the existing water distribution system.

Watermains may be successfully cleaned by a method commonly referred to as "foam swabbing". Flushing or cleaning of mains by any method should be done only with potable water. This condition also applies to pressure testing of the system.

DISINFECTION

At the present time chlorine is the only disinfecting agent in use for disinfection of watermains. Although there are other bactericidal agents which would be satisfactory for disinfection purposes, to date their use has not been generally accepted. Chlorine may be introduced into watermains by the use of the following methods: -

1. Gas Chlorination
2. Hypochlorination

Gas Chlorination

A gas-water mixture is fed into the line with a solution feed-chlorinator. Dry gas may be fed directly into the main using proper equipment to regulate the rate of gas flow and provide effective diffusion of gas into the water

which is simultaneously entering the pipe. It is very important that, in both cases, the feeding arrangement must provide for preventing backflow of water into the chlorine cylinder.

Hypochlorination

A solution of water and chlorine-bearing compounds is most commonly used for disinfection of watermains, because of the relative ease and safety with which these solutions could be handled and applied. Three of the most common chlorine-bearing compounds which are readily available as commercial products and having a known chlorine content are:

1. Calcium Hypochlorite, Trade names - "HTH", "Perchloron" and "Pittchlor"contains up to 70% available chlorine.

2. Chlorinated Lime or "bleaching powder" contains approximately 33% available chlorine.

3. Sodium Hypochlorite a variety of liquid solutions containing between 5% and 14% available chlorine.

These compounds are normally fed as a water mixture of one per cent solution.

APPLICATION PROCEDURES

Continuous Feed

The chlorine, fed either by a gas feeder or a hypo feeder, is introduced into the watermain through a corporation stop at the top of the pipe at the start-point of the new line. Simultaneously, water from the existing distribution system or other suitable (approved) source is introduced into the pipeline undergoing disinfection. The flow of

water and chlorine mixture should be fairly accurately proportioned so the chlorine dosage will be no less than 50 mg/l. Subsequent to filling the pipeline, the chlorinated water should remain in it for at least 24 hours. During this time all new valves and other appurtenances within the system should be operated to expose all components to disinfection. A chlorine residual test should be done at a number of selected locations to ensure that the strength of residual chlorine is 25 mg/l in the system at the end of the 24-hour period. If the residual chlorine is below 25 mg/l at the end of the contact period of 24 hours, the contact period must be repeated with a new solution of 50 mg/l starting strength.

Under certain conditions it may not be feasible to retain the chlorinated water in the pipeline for 24 hours. In such cases, by increasing the chlorine concentration, the retention time may be decreased. This practice, however, should be carried out with consultation and agreement of the local health authority or other agency responsible for proper disinfection of the system. High concentrations of chlorine, 100 mg/l or higher, should be used only in emergencies because of the possibility of damage by highly corrosive chlorine to the pipe, valves, hydrants and other appurtenances.

Slug Method

This method is suitable for use with mains of large diameter for which, because of the volumes of water involved, the continuous feed method is not practical.

Water from the existing distribution system or other approved source of supply shall be made to flow at a constant, measured rate into the newly laid pipeline. The

water shall receive a dose of chlorine, also fed at a constant, measured rate. The two rates shall be proportioned so that the concentration in the water entering the pipeline is maintained at no less than 300 mg/l. The chlorine shall be applied continuously and for a sufficient period to develop a solid column or "slug" of chlorinated water that will, as it passes along the line, expose all interior surfaces to a concentration of at least 300 mg/l ior at least 3 hr. The strength of the chlorine solution should be checked at outlet valves near the upstream ends of the line by chlorine residual measurements.

As the chlorinated water flows past tees and crosses, related valves and hydrants should be operated to disinfect these appurtenances.

Flushing

Following the prescribed retention period, the chlorinated water should be removed from the mains by proper flushing and the piping filled with clean potable water of proven quality. This procedure should be carried out with the assistance of the local P.U.C. and the Health Authority.

BACTERIOLOGICAL TESTING

After the new works have been adequately chlorinated and filled with clean fresh water, a prescribed number of water samples should be collected at predetermined locations and submitted to a laboratory for bacteriological examination. When the laboratory report has confirmed the water in the new system to be bacteriologically satisfactory, it may only then be placed into service to the consumers, but never before. Should the laboratory results prove the water to be bacteriologically unsatisfactory, the disinfection of the

system must be repeated.

When collecting samples, care should be exercised to ensure the sample is not contaminated because of unsanitary sampling techniques. Both the chlorination of the new works and the collection and submission of samples should be carried out by competent and reliable individuals; for example by personnel from the local Health Authority. If these procedures are carried out in a careless manner, it may be necessary to repeat the chlorination process resulting in increased cost and loss of time.

SUBJECT:

CONSTRUCTION OF SEWERS, WATERMAINS AND ASSOCIATED FACILITIES

TOPIC: 13

RESTORATION

OBJECTIVES:

The trainee will be able to:

1. Understand the responsibilities which the inspector has in restoration both in a physical and a public relations sense.

2. Recall which items of the total project are considered restoration and how they should be handled.

RESTORATION

Many years ago, restoration was minimal. Poor compaction, a little bit of stone and a surfacing of emulsion was acceptable for a roadway. Persons fronting the jobs or the maintenance division of the local Works Department were expected to look after ditch and grass restoration and the continuing maintenance or filling in of the slowly settling trenches. Trees were ripped out or the roots were cut causing lingering death. They were seldom replaced or properly pruned and fed. Stream beds were silted in and littered with construction debris, which, hopefully was carried away with the next storm. The Inspector cannot allow this to happen, as the standard of restoration, in the minds of the area politician and the ratepayers, determines whether the job has been successful or has been concluded unsatisfactorily. The contractor, inspector, consultant and agency involved will be informed, in no uncertain words, if the job appears unsuccessful. Good restoration is the "icing on the cake" of any construction job and it reflects on the personal reputation of the Project Supervisor, Inspector and the Contractor.

General

Because restoration generally is done at the end or finalizing of a contract and, at that time, contractors are in a hurry to finish and go about other business, it is quite often given second grade status in the contractor's consideration.

To ensure that restoration is effected to an acceptable degree on MOE projects the requirements of Clause 21 of the Ministry of the Environment General Conditions (May 1976) are enforced.

Clause 21 states:

"21. Restoration

Where the Contractor enters into the lands or buildings of the Province or of any municipality or of any person or enters into any highway or road under the jurisdiction and control of any public authority for the purpose of making any survey, examination, investigation, inspection or other arrangements or lays any pipes or appurtenances in, upon, through, over or under any highway or road under the jurisdiction and control of any public authority, and in so doing disturbs any such lands, building, highways or roads, such lands, building, highways or roads shall be restored to their original condition without unnecessary delay."

This condition is considered minimal and in most cases the Contract Document improves upon the above.

Inspector Responsibilities

The construction inspector, when considering restoration, should do two things before starting the job:

(1) Make a personal inspection of the site with the Contractor and take pictorial records of the entire project. These will establish the basic standard for restoration of the site. Take additional pictures and discuss with the Contractor any areas which may become a point of contention. A good example of this is a sidewalk which is already badly cracked. Any problems such as this should be reported to the project supervisor in order that the contractor not be unfairly forced to replace that which he did not destroy.

(2) Carefully examine the restoration clauses in the contract specifications. They should be strict and should spell out exactly what the contractor is expected to do. After examining the site and specifications,make sure that both you and the contractor understand what is expected. In the event of discrepancies, they should be brought to the Project Supervisor's attention immediately for a decision. Remember, the Inspector is the person who is going to be talking to the irate homeowner who finds his prize begonias flattened, and who also may be paying for a sizable portion, in his taxes, for a job which he didn't want anyway.

There are many acts and local by-laws and policies which involve restoration. For example, one section of the Environmental Assessment Act involves the cleaning up of gasoline spills. The City of Toronto requires only temporary pavement repair; their crews do the permanent repair and then charge the cost to the contractor. The Town of Richmond Hill has a very stringent tree by-law which does not accept a one for one replacement on a mature tree which is on the road allowance and destroyed by a negligent contractor. They insist upon payment under a method of evaluation which could amount to several thousand dollars per tree. The inspector should make every effort to become familiar with these statutes, by-laws, and policies which pertain to the area in which he is working.

Restoration Considerations

Assuming that the job is started and on its way to completion, restoration includes the following items:-

1. Backfilling of trenches. Depending upon the location, these may be backfilled with granular or native material and compacted to a specific Proctor density. If they are not properly

compacted, they may settle at any time from the next rainstorm to many years later. Sagging trench cuts are one of the major nuisances faced by maintenance departments. Many bitter words are passed back and forth by the workmen about the ancestry of the inspector involved in the restoration which they are again restoring.

2. Asphalt or hard surfacing. It is best to save all hard surfacing work to the very end of the job. In fact, many municipalities request temporary repairs with cold patch and wait at least six months before performing a permanent repair. This gives the trench a chance to settle. Care should be taken during construction that all road surfaces be cut vertical to the horizontal plane and in as straight a line with the trench as possible. This saves recutting and widening of the area to be restored.

3. Sodding or spraying of grass. A good grade of sod or grass should be used. This should be placed over a thin layer of topsoil. Sod is usually used for lawn and boulevard restoration in urban areas. It must be constantly watered until there has been a reasonable catch, usually after about a month. Grass seed is sprayed on as a mulch in more rural areas such as fields and ditches. This does not require watering but is slower than grass to take and may require respraying of spotty areas at a later date.

4. Ditches and Culverts. These always seem to be ignored. Ditches are destroyed and only marginal efforts are made to bring them back to original shape. Culverts are allowed to fill in with silt or construction debris or have their ends bashed about by construction equipment and then just left. Possibly this is because they are in more rural areas. Check the ditches including culverts in the area to make sure they are still working properly. Remember, a plugged ditch in a heavy storm could flood out the construction site.

5. Trees and Shrubs. Damaged roots on a tree could kill it up to five years after construction. When a tree is damaged, it must be cared for. Damaged roots means the tree must be fed for several years and the limbs must be cut back. Damaged bark allows the tree to fall prey to insects, disease and fungus, any of which could bring its eventual downfall. A qualified expert must be brought in to take care of any damage done to trees. An amateur might only aggravate the situation.

6. Utilities. These must be properly located prior to construction, supported during construction and in the event of any damage will have to be properly restored.

7. Curbs, gutters and sidewalks. As previously stated, make sure that these items are not broken before construction. When reconstructed, they should match as nearly as possible the existing curbs and sidewalks, e.g. the texture finish of the new walk should match the old walk.

8. Machinery and Office Sites. Oil and gasoline must be cleaned up, all construction structures removed, the ground graded, top soil added and brought back to its original grade and condition.

9. Watercourses and slopes. This has been covered in Topic IV, Environmental Considerations. Slopes which have been destroyed must be structurally restored, possibly with sod and rip-rap. Stream beds silted in with mud and debris must be cleaned out. Check the condition of stream beds a considerable distance down stream as debris is carried far from the actual construction site.

10. Roadway Clean-up. Any construction will track dirt and dust over the various roads which the trucks are using. During wet weather, arrangements should be made to properly wash the mud from the wheels of the trucks at the site before it is tracked throughout the municipality. During dry weather, dust is formed upon the roads. It must be swept or shovelled from hard surface roads and graded to the shoulders or be treated with calcium on gravel roads. Do not place calcium on the dust on hard surfaced roads as it creates a muddy slick and could be particularly dangerous for cars braking and turning.

11. Traffic. A plan of the proposed traffic diversions should be arranged before construction starts. Pre-warning signs should be placed in advance of construction and semi-permanent diversion signs placed with sacking over them ready to be removed on the day of "Start-up". When necessary, temporary roads should be built. When construction is complete, restoration involves removing these signs and filling in the holes, removing the temporary roads and putting the area back in original shape by grading, sodding, etc.

12. Garbage and snow plowing. When working on streets, these services must be maintained and yet there is seldom any specific mention of arrangements in the contract specifications. The wise Inspector, if he suspects there may be any problems with vehicular travel on the street, should check out arrangements.

13. Miscellaneous. All debris along the construction site must be removed; private driveways, walks, fences, lawns and private appurtenances put back in shape; the area swept up and given a good polish.

The weather plays a major part in restoration. Sod and other plants are best put in during the Spring and Fall. Asphalt and concrete is best placed during the warm weather. Very cold weather precludes much restoration other than granular backfill and debris clean-up.

SUBJECT:

CONSTRUCTION OF SEWERS
WATERMAINS AND
ASSOCIATED FACILITIES

TOPIC: 14

TUNNELLING

OBJECTIVES:

Trainee will be able to:-

1. Recall the reasons for tunnelling.

2. Identify and understand the different methods of tunnelling and the problems confronting the inspector when various methods are employed.

3. Understand that conditions vary widely across the Province and realize that the inspector should first concentrate on conditions in his own area.

TUNNELLING

INTRODUCTION

Tunnelling is an expensive way of providing an underground service and there are two main reasons for using this method, namely the size or depth of the service. The open-cut installation of a pipe of 2400 mm diameter or larger in a built-up area would make it impossible to maintain services of water, sewers, hydro, gas, Bell Telephone, fire, ambulance and police, and would completely disrupt the area. The depth required may be greater than can be tackled by open-cut.

Glossary

Primary Lining	-	Support system for ground prior to the installation of the secondary or final lining. In use for a short time in hand mining. May be in place for several weeks in machine mining.
Liner Plate	-	Circular steel liners assembled in sections and bolted together. Plain black liner is used as temporary lining. Galvanized heavy plate may be used as permanent liner.
Grouting	-	The application of cement - sand mixture under pressure to fill voids behind primary or permanent lining.
Spring Line	-	Horizontal Centre line of the tunnel.

METHODS OF TUNNELLING

1. Hand mining

2. Machine mining

3. Pipe jacking

4. Augering

Shaft

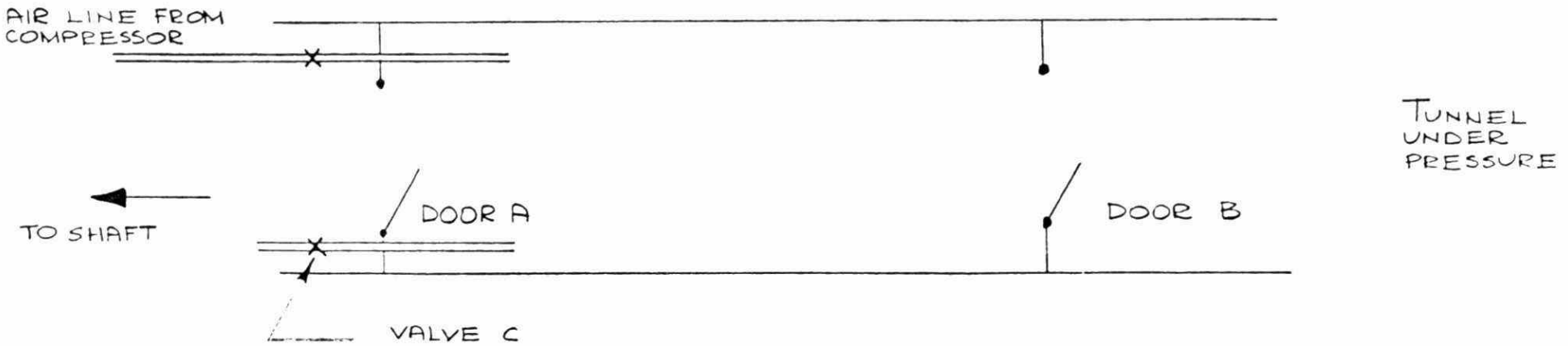
All of these methods require a shaft for access to the work. A sound, safe shaft is of prime importance in all tunnel jobs, however big or small. In soft ground shallow shafts are often supported by timber walers and sheeting. The principles are similar to open-cut timbering. It is very important to see that no ground is lost behind the sheeting. A good concrete collar around the top of the shaft to keep water out is a help. In soft or wet ground a circular shaft lined with liner-plate has the advantage of being bolted tightly together and grout can be placed behind it. This should be done each day during sinking of the shaft. If the shaft is deep or the ground is doubtful, it is an advantage to have the shaft at ground level larger than is required for the manhole or structure to be erected. This allows the use of another method if conditions deteriorate. Sheet piling or H-Beams and lagging may be sufficient to enable the shaft to be completed. If the water problem is serious, the water table must be lowered. Well points or deep wells may solve the problem if the ground conditions are right. As a last resort a vertical compressed air lock may be used. Mains or services near a shaft may cause problems the whole time the shaft is in use. If there is a sewer or watermain close to the shaft, it should be checked and, if necessary, protected so it will not be damaged in the course of the work. If, when exposed, it is found to be defective, a local municipality or public utility will have the responsibility to

repair it. If it is not exposed and is later found to be damaged, it will be difficult for the contractor to escape responsibility. When the bottom of the shaft is reached, a good working slab should be poured if the shaft is to be used as a mining shaft. This should be kept below the structure to be built in the shaft.

Hand Mining

In soft ground it is normal to mine one or two shifts and place concrete on the second or third shift. The primary lining has only to support the ground until the concrete gains sufficient strength to take the load. In good ground steel ribs and wooden lagging are used. In this case, it is often possible to mine ahead for the full length of the plank before it is installed. When conditions become worse, poling plates that are jacked ahead as the excavation advances can be used. These plates must be installed in advance of the bad ground and carried along until required. Precautions should be taken to avoid the plates sticking to the concrete and being lost to the job. The plates should be oiled and may need to be moved ahead slightly each day when mining is not taking place. If a curve is to be negotiated, the radius of the curve has to be taken into consideration in deciding the maximum length of plate that can be used. These plates support the top half of the tunnel. If the invert is soft or running, planking may be used in the invert or complete rings of liner plates may be required. These need to be grouted on a regular basis.

A last resort is the use of compressed air to hold back water, approximately 10kPa of air pressure per metre head of water. The diagram of the airlock shown (Fig. 14-1) is simplified to show only the principles involved. Prior to entering the lock, pressure in the tunnel keeps Door B closed. The lock is entered, then Door A



PLAN OF AIR LOCK

FIGURE 14-1

is closed and air is pumped into the lock. The increase in pressure holds Door A closed. When the pressure equalizes, Door B will open to allow access to the tunnel. On return Door B is closed after entering the lock and air is exhausted from the lock to the outside through Valve C. Door A will then re-open to allow return to the shaft. This method is not used except as a last resort since high medical standards restrict the number of men available to work in compressed air, and reduced working hours as the pressure increases raises the cost considerably.

In hand mining the excavation will not exactly conform to the primary lining therefore there will be voids to be filled by pressure grouting. Grouting is not considered a high priority by most contractors because they tend to stress progress as so many feet per day, and this might be slightly reduced by the time taken to grout. The frequency with which grouting is required depends on the type of ground. Agree on a regular schedule of grouting with the Contractor. Watch carefully for voids and lost ground, as if not caught quickly they will eventually show up on the surface. It will funnel quickly to the surface in sandy ground.

Ground conditions can change daily so the inspector should keep a close watch on the situation and discuss any changes with the Contractor.

A bulkhead is required at the face at the end of each shift. The strength of the bulkhead will depend on the stability of the ground and the length of time that it is going to be left in place. The bulkhead should be checked regularly when the job is closed down for any reason.

Mining Machines and Shields

A shield is a steel tube that is pushed ahead of the primary lining by a series of hydraulic jacks and provides protection for the work. The primary lining is built inside the tail of the shield and may be expanded to reduce the gap between the lining and the ground after the shield has moved ahead. If cast iron or concrete segments are built behind the shield as a permanent liner, they must be grouted. By closing the face, the ground is prevented from running in. Mining is done by hand. This gives a better and safer job but not necessarily a quicker one. Shields can be used under compressed air. Grade checks are important because changes cannot be made quickly.

A full-face mining machine cuts the ground with revolving cutters and deposits the muck onto a conveyor. The machine is moved in the same way as a shield. The primary lining is erected in the tail of the machine. It is often ribbed with wood or concrete lagging. The efficiency of a machine operation is governed by the speed with which the muck can be moved from the back of the machine. In most cases, the machine is able to dig far more muck than the equipment behind it can move away. Well-placed switches, big trains, powerful locos and muck storage areas near the top of the working shaft are required for maximum efficiency. It is preferred to leave the primary lining alone as long as possible to allow maximum working room. In any mining operation, rocks in the face are unpredictable. Test boreholes are too far apart to give a fair indication whether or not boulders will be encountered. If the rock is too large to come through the face of the machine, it is a slow and tedious job to break it up. A rock in the invert is more difficult to deal with than one at spring line or above.

An Alpine miner is a mining machine that is independent of the shield. It has a single arm with a cutting head which can be used to cut a circular or square section. When used with a shield, a control ring can be used to enable an exact circle to be executed. Any mining machine operates best in homogeneous ground as a mixed face can cause considerable problems because the cutting device which is good for one part of the face may not operate as well on the other part. A mixed face of clay and rock is a very difficult face for any machine to tackle.

Pipe Jacking

In principle, pipe jacking can be compared to mining with an open-face shield. The front pipe has a cutting ring mounted on it acting as the shield. In the shaft there is a jacking block sufficient to take the strain of pushing the number of pipes necessary to complete the heading. The hydraulic jacks push one pipe length, are then withdrawn and a further pipe inserted. Bentonite grout is pumped through a hole in each pipe to make it easier to jack. On days when the jacking and mining operation is not taking place, the jack should be operated to move the pipe a few cm. This will avoid start-up difficulties after a delay due to breakdown of the equipment or a holiday. Because of the movement of the pipe the survey checks have to be made from the shaft by laser or instrument. Accuracy is essential since to correct line or grade is very difficult. If water is encountered, deep wells or well-points may be required. The difficulties of working through a vertical airlock make the use of compressed air almost impossible.

Augering

This operation is normally used for small, shallow pipes of 300 to 375 mm diameter under roads and rights-of-way.

Twelve metres is the limit with a reasonable chance of maintaining line and grade. Local mains and services are sometimes a problem. A small percentage of holes may need to be abandoned and re-drilled. Since the hole is augered and the pipe placed without workmen entering the excavation, the type of pipe joint is important.

The joint has to be made and the pipe then moved into the hole. The length of pipe and therefore the number of joints, is governed by the maximum size of shaft possible. In soft or sandy ground a casing is needed and the pipe is grouted in. The casing is jacked in with the auger and is kept just behind it to prevent loss of ground. The latest developments in this field allow for boring of pipes up to 900 mm diameter.

Rock Tunnels

A tunnel excavated by blasting is similar in principle to hand-mining. Removing loose rock by scaling is important. If the concrete is not poured close to the face, rock bolts will need to be installed in a pattern suitable to the type of rock. Steel wire mesh may be used as an additional safety precaution. The inspector should know and check the blasting pattern, method of loading and size of charge to be used. It is important in a built-up area that the amount of explosives used be controlled to reduce the possibility of damage to private property. Seismic tests are usually made on a regular basis and the inspector should be familiar with the appropriate clauses in the Specification and ensure that they are followed.

PUBLIC RELATIONS

As the tunnelling shaft may be outside a taxpayer's property for as long as two years, care should be taken to

provide an atmosphere in which people can live. The inspector is the key man because he is the Owner's representative who is seen all the time. It is helpful if politicians are briefed ahead of time. An Alderman who understands the problems can be of great assistance. The inspector is responsible to see that the working area is set-up as required by the Specifications.

At the time of start-up it is useful to have some improvements made that can be left. Check any changes that may be required because of local factors. Some people can never be satisfied. Never improve the situation for a complainer at the expense of a reasonable taxpayer. Encourage people to explain their problems on site before calling their Alderman. A project involving explosives is a special problem. An inspection by insurance representatives is usually made prior to the start of the job. A letter explaining the project to the local inhabitants should be sent out by the Owner, municipality or government department. A quick response to complaints should be made. Do not get involved in any claims; always ask that these be made in writing.

INSPECTOR'S DUTIES

These are not difficult as at first they may appear. One of the most difficult things to get used to is not being able to see where you are going. Some inspectors turn down a tunnel job before studying carefully what is involved.

An inspector's first experience in tunnel work is often obtained on a project that consists mainly of open cut work but does have some small tunnels under roads and rights-of-way incorporated in it.

It is easier for a man with mining experience to become a tunnel inspector. However, it is possible for a concrete inspector to work in a tunnel with the concrete shift and then enlarge his experience to include mining.

Handmining

Check line and grade and size of excavation to ensure that it is large enough. Safety of the primary lining is important. Check support of the lining, particularly the centre rib if two planks are used and the foot of the centre rib if a full rib is not used. Watch for changes in the type of ground or for wet conditions as more or stronger primary lining may be required. On the concrete shift, check the invert when forms are stripped, as it quickly becomes covered with dirt on the next mining shift. Check that forms are clean and oiled before re-use. Check line, grade and clearance.

In bad ground make sure you know the tolerance allowed in concrete thickness before reinforcing steel or later remedial work is required. Sometimes, the pour is allowed because conditions are becoming worse. Further mining should not be allowed until a method to overcome the problem is agreed upon.

Curing conditions are normally good in a tunnel. Encourage patching and grouting as the job proceeds.

Machine Mining

Check line and grade which is normally set by laser. Check the type of ground being excavated. If the machine has gates that can be used to close off the face, check that these are closed when the machine is not operating. When the concrete is kept back from the machine, check for any sign of strain in the primary lining. The concrete operation is basically the same as other methods except that the pours are much larger.

Pipe Jacking

Check line and grade if set by laser or ensure that the surveyor makes regular checks from the shaft. Check

that there are no signs of damage to intermediate pipes or joints. Check for type of ground and any loss of same.

Safety

Safety is a bigger problem underground. We are dealing with heavy loads and equipment in a confined space, and great care is required. We rely on artificial light and must be prepared for a power failure and use of emergency lighting. We must watch for moving trains. Hands and feet are very vulnerable where concrete forms, conveyors and muck cars are concerned.

The Construction Safety Act is enforced by Provincial Safety Inspectors who visit projects approximately once a week. This does not relieve the resident inspector of a moral responsibility for a safe operation. The interpretation of the Act can be discussed with the Provincial Inspector on his visits to the site.

Surveying

When the tunnel is on a straight line and steady grade, checking is comparatively simple. In small tunnels the line is set from vertical strings hung from the crown, and grade is checked by horizontal strings looped on to spads at the sides of the tunnel. The inspector must remind the surveyor to extend line and grade closer to the face before sighting becomes difficult.

When a job is proceeding well and steady progress is being made the surveyor will have a regular schedule for his work.

Survey on a curve is more difficult. It is of the utmost importance that you understand the method that is being used to lay out the curve. There are several ways that

the line can be set ahead on chords or tangents to the curve. To check properly it must be carefully explained by the Engineer or Surveyor.

When a laser beam is being used it must be checked regularly to ensure that it has not been knocked or moved by vibration. The surveyor will provide the information necessary to check laser alignment.

SUBJECT:

CONSTRUCTION OF SEWERS WATERMAINS AND ASSOCIATED FACILITIES

TOPIC: 15

BLASTING CONTROL

BLASTING CONTROL

LEGISLATION

Federal

The supplying, hauling and storing of explosivies and accessories is covered by Federal Statute under the rules and regulations of the Explosive Division, Department of Energy, Mines and Resources. In addition, under these regulations each user of explosives is required to maintain a strict record and control of the explosive stock in his possession and to be accountable for the disposition of each item of explosive product or accessory.

Provincial

The general stipulation that every precaution shall be taken in the handling, storage, transportation and use of explosives to protect persons on a project is covered by Ontario Regulation 419/73, section 104.

There is no provincial licensing requirement for blasters/powdermen in Ontario at the present time. However, under Ontario Regulation 419/73 made under the Construction Safety Act, 1973, and similar requirements contained in Part IX of the Mining Act, it is required that a competent person shall be appointed to be in charge of and to personally supervise all blasting operations. The term competent is defined as qualified by knowledge, training and experience to perform an assigned task. This legislation thus makes it the responsibility of employers and their project superintendents to ensure the competence of persons where prescribed by the Regulation.

Specific requirements and restrictions pertaining to explosives are contained in Ontario Regulation 419/73, sections 104 to 113 and 204 to 213. Special note should be made of section 112(2) (a), which prescribes that a drill hole shall not be drilled within twenty-five feet of a hole being loaded with or containing explosives. This restriction is subject to section 112(3) which permits it to be waived, provided that,

1. a specification has been prepared in writing by a professional engineer,

   (a) describing the precautions to be taken to prevent the accidental detonation of the explosives in a loaded hole by the drilling of another hole, and

   (b) bearing the signature and seal of the professional engineer.

2. a copy of the specification referred to in clause (a) is kept at the project while the drilling and blasting to which it refers are being carried out; and

3. the drilling and blasting are carried out in strict compliance with the specification referred to in clause (a).

Municipal

A few individual municipal authorities, notably those of the Cities of Ottawa and Hamilton, require that blasters/powdermen hold current local licenses while blasting within their jurisdiction. In general, however, municipal involvement is limited to the granting of blasting permits for specific projects or facilities.

Since May, 1976, an approved Model Municipal Noise Control By-Law, including restrictions on the permissible levels of noise and ground vibration from blasting, has been made available to individual municipal authorities by the Ontario Ministry of the Environment, should they wish to adopt such a by-law. Some municipalities have already passed the necessary enabling legislation and there appears little doubt that the current restrictions contained in the Model By-Law will become accepted standards for the control of noise and ground vibration effects from blasting operations in Ontario. The specific limits contained in the Model By-Law will be dealt with in more detail in a later section.

CONTROL PROCEDURES

Pre-Blast Surveys

Blasting is an effective and controllable engineering procedure, but it is also a spectacular and sometimes startling operation which can lead to the formation of false impressions in the mind of an observer, particularly if that observer is also a property owner.

Nowadays, in almost every project which involves any degree of blasting, it has become the rule rather than the exception for claims to be sumbitted by adjacent, and sometimes distant, property owners for damage allegedly caused by the undesirable by-products of the detonations. Very often, these claims are honestly made but nonetheless invalid.

Residents of adjacent properties, suspecting that if the blasting disturbs them personally it must also be capable of affecting their homes structurally, begin to look at the plaster, concrete and masonry components more closely than ever before, and not surprisingly, they find cracks which they have not previously noticed but which have quite possibly been in existence for some time.

It is clear, then, that human response alone is a most unreliable indicator of the damaging potential of ground vibrations, and that other more convincing evidence is required for the evaluation of the validity of claims for blasting damage.

Ideally, therefore, before blasting is carried out on any site one should commence with a careful examination, preferably including photographs, of all buildings liable to be within the range of perceptible vibration from the source, or at least all buildings adjacent to the perimeter of the site. In the case of a heavily built-up area, a maximum range of 60m in any direction from a proposed blasting location is suggested.

If this pre-blast survey is carefully made, all existing cracks and defective conditions can be recorded and their number and location can be brought to the attention of the homeowner. Should a claim for damage subsequently arise, a post-operation check can establish which defects have occurred within the time frame of the blasting operations concerned.

Monitoring and Criteria

When a commercial explosive is detonated, only part of the energy released is used up in accomplishing the intended purpose of the detonation, i.e. generally, breaking rock to facilitate its removal in easily handled fragments. Hopefully, the proportion of energy so used will be large. But no matter how efficient the blast may be, some excess energy will always be available for dissipation as undesirable side-effects, any or all of which, if uncontrolled, may threaten the structural integrity of adjacent

vulnerable buildings, structures or services. These unwanted by-products of detonation are flying rock fragments, air concussion and ground vibrations.

The control of flyrock is largely a matter of common sense. If the shot is not obviously overloaded, if the holes are adequately stemmed and have sufficient collar, and if the exposed surface area involved in the blast is adequately covered where necessary with good quality blasting mats or a sufficient depth of sand or other suitable material, then the flyrock problem will be controlled and the hazard therefrom greatly reduced if not entirely eliminated.

Air concussion effect, which depends on the sound pressure wave level, is usually only a problem at relatively close quarters, and the most common hazard which it presents is window-glass breakage. This hazard too can be reduced by adequate stemming and the avoidance of overloading.

The damaging potential of ground vibration from blasting depends on the displacement and the frequency of the vibration. Neither of these two characteristics alone will damage a structure. The "particle velocity" of earthborne vibration is now generally accepted to be the best measure of damage potential, since it appears to combine displacement and frequency in the most significant manner.

It had been established from practical experiments by investigators in this country and abroad that particle velocities of between 2.8 and 3.2 inches per second in any one of three mutually perpendicular planes were normally required to reopen or extend old plaster cracks or to produce new hairline cracks by ground vibration. With appropriate conservatism, the investigators agreed that a peak particle velocity level of 2.0 inches per second would be safe with

regard to plaster cracks in residential-type structures.

Similarly, the limiting criterion for air over-pressure effect, to protect the structural integrity of the building closest to a blasting operation, had been established as that associated with an impact noise level of 140 db.

The Model Municipal Noise Control By-Law referred to in an earlier section, establishes a new vibration cautionary limit of 1.25 cm/second and a peak vibration velocity limit of 5.0 cm/second. The latter limit, which is to be permitted if the person in charge of a blasting operation carries out routine monitoring of the vibration velocity, is the metric equivalent of 1.97 inches per second and as such, appears on the surface to differ little from the previously accepted limit of 2.0 inches per second. The Model Municipal Noise Control By-Law peak vibration velocity limit however, is defined as the magnitude of the vector sum of all three components and not just the maximum in any one plane, so that a considerable reduction in the previously accepted limit has in fact been achieved.

In place of the previously accepted limit of 140 db. for impact noise level, the Model Municipal Noise Control By-Law establishes a new Concussion-Cautionary Limit of 128 db., and a Concussion-Peak Overpressure Level Limit of 136 db. The latter to be applied if the person in charge of the blasting operation carries out routine monitoring of the overpressure level.

As presently written, the noise limitations described above apply only to concussion resulting from blasting operations in a mine or quarry, but it appears likely that

they will in time receive more general application and ultimate acceptance as a replacement for the previously accepted impact noise level limit of 140 db.

On any proposed construction site, it is advisable to begin blasting in a non-critical area, or alternatively, to detonate a series of conservatively light test blasts prior to the commencement of production blasting. These initial detonations should be monitored with two or more portable 3-component velocity-recording seismographs to establish the peak particle velocities produced and to determine the rate at which these tend to attenuate under the prevailing site conditions. An appropriately safe explosive load versus distance relationship can then be readily established and the maximum permissible explosive weight can be calculated for any critical distance from the initial production blast. By continuing to monitor the production blasting as it proceeds, on a continuous or intermittent basis, the explosive load versus distance relationship may be amended where necessary as site conditions change. Evidence of the continuing safe level of vibration intensity can be accumulated and stored in the form of permanent photographic seismic recordings, which are acceptable in court in the event of ensuing litigation.

Effects of Patterns and Procedures

As well as controlling the mechanics of fragmentation of the shot, much of the control of the potential side-effects discussed earlier is dependent upon the particular blasting pattern and procedure chosen or designed for this purpose.

The more efficient a shot becomes, the less surplus energy is available for dissipation as side-effects. The production of ground vibration in particular is largely governed

by the distribution of explosive load by delay period detonation throughout the shot. Generally, it can be assumed that the intensity of ground vibration produced by the total blast will be no greater than that produced by the maximum load designed to be fired on any individual delay period.

In rare cases, an exception to this rule can occur in certain specific geological and ground-water conditions, where propogation between holes may take place by sympathetic detonation without the benefit of the designed delay period. Where such conditions are known to exist, and where such propagation is anticipated, explosive products which are not readily propagable may be used if the explosive weight detonated instantaneously is liable to be critical.

Ground vibration intensities will invariably be greater per kg of explosive product for shots with very limited relief, such as sinking-cuts, or virtually no relief, such as pre-splitting, than for production blasting involving at least one vertical face, as in trench blasting, or several faces as in many instances of highway construction. Production blasting in tunnel is an exception, however, since each advance involves the horizontal equivalent of a sinking-cut blast and the ground vibration intensities will remain relatively high per kilogram of explosive product in comparison with other types of production blasting.

In situations which appear likely to be critical, ground vibration intensities from trench blasting can often be reduced appreciably by mucking out the previously blasted material up to the face of the next shot before firing, to provide a free face effect rather than a buffer.

Sewer and watermain contractors will sometimes use existing undisturbed overburden as a blasting mat by

drilling through this material and loading the rock beneath. This procedure can be both economical and effective for the control of flyrock if the overburden is within an acceptable range of depths. Again however, in certain cases this limitation to normal relief during the blasting procedure may cause ground vibration intensities to rise to a critical level.

In view of the foregoing, the initial program of test monitoring of seismic effects referred to earlier should be carried out wherever possible under the most extreme conditions likely to be encountered for the production of a high intensity of ground vibration.

CONTRACT SPECIFICATIONS

There is often considerable variation in requirements concerning blasting control from project to project, even when the projects themselves appear almost identical in other respects.

Generally, if blasting has been anticipated, the Contractor will be required to retain the services of a qualified blasting control consultant to review and approve the proposed blasting method, recommend precautionary measures, and submit a report on these matters to the Engineer. This may include the initial test blast monitoring and the recommendations resulting therefrom.

The specifications may also define the degree and frequency of further monitoring to be provided, from continuous full-time service to intermittent service at specified intervals of time or distance, or at any change in pattern and method, or explosive quantity.

A pre-blast survey of adjacent vulnerable properties may be specified in the contract documents but even if it

is not, the Contractor may have such an examination undertaken on his behalf, either at the instigation of his Insurers or on his own initiative.

Some specifications will stipulate a maximum permissible ground vibration intensity level at the nearest vulnerable structure or service. If the Model Municipal Noise Control By-Law is not applicable or specified, the restriction mentioned will most likely be a peak particle velocity of 5.08 cm/sec or an Energy Ratio of 1.0. Energy Ration is a more or less obsolete term but the two restrictions can be used almost interchangeably, since an Energy Ratio of 1.0 is the equivalent of a peak particle velocity of approximately 4.88 cm/sec.

SUBJECT:

CONSTRUCTION OF SEWERS WATERMAINS AND ASSOCIATED FACILITIES

TOPIC: 16

BASIC ELEMENTS OF CONTRACT DOCUMENTS

OBJECTIVES:

The trainee will be able to:

1. appreciate the features of a contract
2. be aware of the different types of contracts
3. understand the basic elements of contract documents
4. realize the means to discharge a contract

BASIC ELEMENTS OF CONTRACT DOCUMENTS

GENERAL

Normally the Owner, the party desiring to have a project constructed is not adequately qualified to develop and direct such work and thus will employ specialists and skilled advisors to plan and supervise the execution of the work within stipulated cost and time limits. This specialist is usually the Engineer and in cases of building construction, the Architect. The Engineers does not possess the plant and organization to undertake the actual work and therefore it is normally arranged that another party, called a Contractor, particularly skilled in construction operations, is vested with the actual execution of the work under the general supervision and direction of the Engineer.

To ensure that all aspects of the "arrangement" are precisely identified and clearly understood, the Owner and the Contractor enter a contractual agreement outlining all of the important aspects of the work to be done.

THE CONTRACT

In simple terms, a contract exists when one party makes an offer to undertake certain works, and another party accepts the offer. An acceptance of an offer may in certain cases be deemed to consumate the agreement even though the formal signing of the agreement has not taken place. Another way to describe a contract may be a promise or a set of promises which the law will enforce. The laws of contracts differ from other branches of the law in the respect that the parties to the contract make their own rules as to what shall bind them.

In addition to the requirement of an offer by one party and acceptance of the offer by another party, the contract is characterized by several other essentials. The persons entering into a contract must be of legal age and cogniscent of what they are doing. Thus, a contract with an infant, an intoxicated or insane person would be rendered void, or at least voidable.

The parties entering into a contract must have a mutuality of mind, that is to say, they must understand each other as to exactly what is the work that is to be undertaken and that there are no undisclosed pertinent facts.

Finally, a contract between the parties must be legal, thus a party cannot contract itself into undertaking an illegal action. Normally there are two major categories of contracts:

1. Unsecured cost contracts, and

2. Secured cost contracts.

There are many breakdowns of the above two general categories but it is evident from the classification that the first category does not guarantee the Contractor that he will recover all amounts that he has expended on the works whereas the second does. Most Government agencies deal with contracts of the first category almost exclusively.

The unsecured cost contracts have two major forms currently in use: the Lump Sum Contract and the Unit Price Contract. These are discussed more fully in the following section.

TYPES OF CONTRACTS

There are several types of contracts which are commonly in use today, and the nature of the project, its

location, the complexity of the work, and the proposed scheduling of the project, all influence the type of contract most suitable for a given project.

The following are the more common types of contracts:

Lump Sum Contract

In a lump sum contract, the Contractor undertakes to carry out the Contractor's works for a fixed sum of money. This form of contract is used where the work is reasonably certain in character and extent. Under this contract, the onus is on the Contractor to work more efficiently, for whatever difference exists between the contract lump sum price paid to the Contractor and his actual costs represents his profit or loss. This type or contract is most common for buildings, bridges, pumping stations and treatment plants.

In a lump sum contract, the Inspector has the responsibility to keep good records and to ensure that the work is carried out in accordance with the contract specifications, with no resulting quality reduction.

Unit Price Contract

This type of contract incorporates a Schedule of Quantities in which all of the items of work are listed and priced on a unit price basis, to give a total contract price. This type is primarily used on sewer, watermain and roadwork projects and on excavation jobs where it is difficult to state the exact volume of earth and rock to be encountered. In this contract the Contractor is paid for whatever work he carried out and one can see that the final value of the contract can fluctuate significantly, depending on how accurately the original quantities were estimated.

The role of the Inspector in this type of contract is to ensure that all the work completed by the Contractor is properly measured and documented and that the work has been carried out in accordance with the drawings and specifications.

Cost Plus Percentage Contract

In a cost plus percentage contract, the Contractor is paid the actual cost of work, plus an agreed percentage of the actual or allowable cost to cover overhead, profit, etc. It is useful in an emergency, when there is insufficient time available to prepare a detailed scheme or when the work cannot be clearly identified because of uncertain conditions.

The major disadvantage of this form of contract is the lack of incentive for the Contractor to complete the work as quickly as possible or to try to reduce costs. While there is some assurance to the Owner that there are no extravagant profits being paid to the Contractor, it is necessary to closely monitor and control the Contractor's records relating to the cost of the work to ensure that proper accounting is carried out.

Cost Plus Fixed Sum Contract

In this form of contract, the Contractor is paid the actual cost of the work plus a fixed sum, which has been previously agreed upon and which does not fluctuate with the cost of the job. It is superior to the cost plus percentage contract, as there is some incentive to the Contractor to complete the work as speedily as possible, although once again, the work records should be carefully checked and monitored.

Cost Plus Fixed Sum, with Bonus or Penalty, Contract

In this type of contract, the Contractor is paid

the actual cost of the work with a fixesd sum previously agreed upon. In this case, however, if the Contractor is able to reduce the cost of the work below the original estimated costs, he receives an agreed percentage of the savings, while if he allows the cost to exceed the estimate, he is penalized by deduction from the agreed fixed sum, a percentage of the excess of the actual amount over the estimated cost. As this form of contract incorporates an incentive to carry out the work as quickly and cheaply as possible, it constitutes the best of the "cost plus" type of contract, from the Owner's point of view.

CONTRACT DOCUMENTS

Every written contract must define exactly the rights and obligations of the parties involved, as well as provide an explicit description of the work to be completed. In addition, as the offer and the acceptance are part of the contract - since it is through them that the contract is created - there should also be a formal contract agreement, particularly in large complex projects, which involve several interested parties.

Accordingly, the usual construction contracts for typical Civil Engineering projects include the following basic elements:

Agreement
General Conditions of Contract
Specifications
Special Conditions
Contract Drawings
Tender

On the more complex contracts, involving a number of different facets, one may often encounter in addition:

Information to Tenders
Addenda, if any
Suplementary General Conditions
Supplementary Specifications

Each element provides a specific contribution to the mutual understanding and makes the contract a clear, precise and legally binding document.

Agreement

The Agreement is a document which formalizes the contract by bringing together all the other contract documents by reference to them. The purpose of the Agreement is to record the business and financial arrangements between the Owner and the Contractor with respect to the work. This is the most formal part of the contract documents and should be entirely devoid of technological material making it unnecessary for field staff to have access to it.

In the Agreement, the Contractor covenants to construct, complete and maintain the works in accordance with the contract, and the Owner convenants to pay the Contractor at the times and in the manner prescribed by the contract. This is the document that is usually signed, sealed and witnessed by both parties.

The agreement also sets out the order of precedence of the various contract elements in the event that there is a conflict between clauses in two or more of these elements. The problem of conflicts is discussed in more detail later in this topic.

General Conditions of Contract

The General Conditions define the legal rights and obligations of the Owner, the Contractor and the Engineer, the Owner's agent, and may be described as the regulations

under which the contract will be peformed and as such, set the pattern for administration of the contract.

Although the General Conditions cover a number of topics of a work project, the Owner will arrange and adapt the topics he finds necessary to suit his own unique requirements.

Typically, the topics covered in the General Conditions fall in one of the groups outlined below.

GROUP	TOPICS
Scope of Work	Definitions, estimated quantities, changes and alterations, extra work, acceptance.
Control of Work	Engineer's authority, claims and negotiations, conflicts and omissions, line and grade, damage by vehicles.
Control of Materials	Supply of materials, source of supply, defective materials.
Legal Responsibility	Contractor's responsibility for damages, liability insurance, access to properties, explosives, observance of laws, statutes and regulations, notice to Contractor, notice to Owner.
Prosecution and Progress	Time and order of completion, extension of time, assignment and subletting, non-fulfillment of contract, suspension of work,

losses and damages, labour disputes, obstructions, limitation of operations.

Payment — Price for work, advance payments, payment for extra work, measurement of materials, Contractor's discharge of liabilities, payment of workmen, books, payrolls, accounts and records.

Specifications

This document sets out the technical requirements of the work. It describes in detail the work to be executed under the contract and the nature and quality of the materials and workmanship. As well, it acts as legal evidence in the event of litigation.

For each phase of the work, there is a specification prepared to describe in clear, concise and simple language, exactly what is required. While there are various forms in which the Specifications may be written, it is essential that certain information is brought out clearly. The following headings indicate the key points to be included.

1. Description

   Provides a full explanation of the job task and of what is expected of the Contractor in carrying out his work.

2. Materials

   Identifies the technical requirements of all the materials necessary to complete the work.

3. Construction

Advises the Contractor of the final product to be provided and of the general construction practices to be followed. Where the Contractor feels that he has a more efficient or economical approach he would contact the Engineer for approval to use his alternative method.

4. Measurement

Outlines the method of measurement to be used in determining the quantity for which the Contractor will be paid at the contract unit price.

5. Payment

Describes the basis of payment, specifying precisely what the Contractor is required to do for the contract unit price of the particular item.

Special Conditions

This document is in reality a supplement to the General Conditions discussed earlier, and it identifies the unique peculiarities of the specific project. Consequently the Special Conditions are prepared separately for each project and deal with matters such as duration of construction, work program scheduling, damages payable for late completion, maintenance period after completion, unusual administrative arrangements, special constraints placed on the Contractor and noteworthy site conditions.

Contract Drawings

These are the pictorial representations of the

project, showing clearly, simply and completely the extent of the works to be carried out under the contract. The drawings should also indicate all pertinent existing information such as contours, man-made and natural surface features, and sub-surface conditions where applicable. It is essential that the drawings be accurate, with legible and adequate dimensions to properly convey the required information to the Contractor. It has been proven that the better the quality and completeness of the drawings, the less opportunity there is for disputes and misunderstandings.

Tender

This document lists the various items of work included in the project along with their estimated quantities. Often otherwise referred to as the schedule of quantities, schedule of unit prices or schedule of rates, this document provides a basis on which Contractors can prepare bids and when the various Tenders are received, affords a means of comparing the prices. After the contract is signed, the Tender forms the basis for valuation of variations and extra work; while during actual construction, it is valuable in the preparation of progress payment certificates.

Information to Tenderers

This section provides the would-be bidders with the information regarding the tendering procedure. The type of information provided includes:

1. availability of tender documents
2. time, date and place of tender closing
3. amount of tender deposit
4. necessary bonding and certifications
5. additional required information about the Contractor

6. project description
7. special tendering requirements
8. interpretation and discrepancies

Addenda

Changes made to the project after advertising but prior to Tender close are designated by means of addenda, issued to all plan-takers and are considered as part of the documents. As part of the Contractor's submission of his Tender, receipt of the addenda must be acknowledged and the requirements stated therein included in the submitted Tender price.

Supplementary General Conditions
Supplementary Specifications

Under special circumstances, it may be necessary to include Supplementary General Conditions or Supplementary Specifications into the contract documents. Although these items may alternatively be included under Special Conditions, setting them out separately emphasizes them - a useful alternative in cases where site conditions or project administration dictate the needs for the modifications to the clause in the General Conditions.

CONFLICTS

All of the elements discussed above and as set out by the Consulting Engineer, constitute the contract documents and as such they should be in agreement amongst themselves. However, as sometimes occurs, there is a conflict between two or more of the elements and the courts historically have indicated that all of the documents are not of equal status.

The most common contractual document used in Canada for almost all private arrangements is the Canadian

Standard Construction Document, which is available for various forms of contract including the stipulated price contract and the stipulated unit prices contract.

This document outlines the priorities in the event of conflicts between contract document as being:

1. Documents of a later date shall govern.

2. Figured dimensions shown on the drawings shall govern even though they may differ from scaled dimensions.

3. Drawings of a larger scale shall govern over those of smaller scale of the same date.

4. Specifications shall govern over drawings.

5. General Conditions of a contract shall govern over Specifications.

6. Supplementary General Conditions shall govern over the General Conditions of the Contract.

7. The Agreement shall govern over all Documents.

In the event of an Addendum being issued, it shall supersede the Supplementary General Conditions, but not the Agreement.

Although this is a common and well-known approach to the question of conflicts between contract documents, other agencies such as the Ontario Ministry of the Environment and Ministry of Transportation and Communications have developed separate formats which are only slightly different but suit better the particular Ministry's purposes.

In any case, whatever the order of precedence may be for a contract, it should nevertheless be clearly set out in the Documents to ensure that such disputes can be quickly resolved.

DISCHARGE OF CONTRACTS

A contract is said to be discharged when the agreement between the parties is terminated, and the rights and liabilities arising out of the contract are as a result extinguished.

This termination may be accomplished in several ways.

1. By Agreement — The parties may agree to terminate the contract by one either waiving his rights, or releasing the other from his obligations.

2. By Performance — Complete fulfillment of the terms of the contract in every respect, by both parties, discharges the agreement entirely.

3. By Breach — Whenever one party breaks an obligation which the contract imposed upon him, he has breached the contract. Depending upon the circumstances, the other party may discharge the contract.

4. By Impossibility — Legal impossibility or impossibility of performance may arise after the contract by law from the date when the cause of action arose

and if the action is not commenced by that date, the contract is considered void.

CONCLUSION

This brief discussion on the basic elements of contract documents provides only a simplified summary of the various aspects of contract preparation. Specific technical or legal points should be discussed with legal counsel, if there is some concern about inherent implications and responsibilities related thereto.

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